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# MODERN SCIENTIFIC KNOWLEDGE of Nature, Man, and Society

By

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WITH COLLABORATORS



THE RONALD PRESS COMPANY  
NEW YORK

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## FOREWORD

Modern democracy, with its freedom, has produced a race of specialists. The drift, at first scarcely perceptible, now moves forward at a rapid pace. In the sciences, business, education, recreation, and community welfare activities the effect is cumulative. Each science rapidly gathers around it a literature so extensive that the mind, even of the expert, fails to keep pace with more than the major results of research in a single field. Each of the many arts develops a highly elaborated technique—the mastery of which requires specialization and collaboration. Institutions multiply—with little regard for needs of integration and unification. A common sense of contact one with another is lost. So complex has the scheme of living already become that the individual is confused.

In no relation is there a deeper sense of need for perspective than in the field of education. Particularly is the student confused when he enters a modern university. Thrown largely on his own resources he must choose between an endless variety of highly specialized educational offers. An elaborate curriculum lies before him and decision must be made; but until recently little thought was given to providing the student with adequate means of knowing what are the interests and what are the leadings of the many schools and departments of institutions, even though by force of circumstances, he must choose between them.

The feeling of need of perspective is shared by faculty as well as students. The rapidly growing subject matter of the sciences radiating from the older subjects of cultural interest is impressive; but it is also challenging. At first the universities sought to preserve a balance by restricting electives. Then they turned to "combination courses." Among the first was course "English 28" offered by Harvard to give the student a general survey of English literature before permitting him to make his major choices and exercise his elective privilege. The related faculties of history and the social sciences in the large universities early saw a similar need. As a result combination courses were offered,

such as the freshman required course on "Contemporary Civilization" at Columbia. Many colleges and universities have adopted similar devices.

Seemingly the general survey of the sciences has come to stay. The curricular title by which these cultural surveys are now known is "orientation course"; and in many institutions (Stanford, Dartmouth, Minnesota, Pennsylvania, California, etc.) the course thus named is "required" in the freshman year. Not only are universities and colleges seeing the need for a course which will introduce the curriculum to the student and the student to outstanding educators, but high schools and academies are recognizing a similar need. This accounts for a return to a study called "general science."

Still more insistent is the demand of a large reading public for a well-balanced statement of scientific conclusions which will enable the individual to see the world as it is and map out his mental course, as a mariner would use a chart in unknown seas. This demand is expressed in the millions of volumes sold during the last ten years on general science, history, and philosophy. More and more, a sound public opinion depends on scientifically established premises for reasoning. Why be guided by guesses and custom when beliefs and principles that are true to the facts can be popularized? Most problems have become group problems. They must be solved by group deliberation.

The capacity of a community of minds to think together; the ability to develop common social feelings in harmony with principles of right living; individual attitudes taken which permit groups to reach common determinations—to have a common will; all of these are aptitudes made possible by scientific knowledge. Public opinion is the thought which is shared. Public sentiment is not the sentiment of teachers and preachers; it is sentiment organized around common beliefs. It is of utmost importance that commonly shared beliefs shall be based on evidence and interpretations that are scientifically sound. Myths, dogmas, bold assertions made by autocratic or self-seeking leaders, and inherited prejudices must give way to educational and publicity procedures adapted to training individuals and groups to think, feel, and act in ways that are consistent with knowledge of things as they are. For this reason, the finger boards must be put upon

the roads that lead to individual opportunity for scientific training. "Orientation"—the ordering of the universe in the mind—must be thought of as the chief aim or end of education for citizenship.

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What is undertaken in this volume may be gleaned from the table of contents. The purpose is to present in thirty-one short chapters a vision of the world in which we live as seen by men of science. The first three chapters (Part One) are introductory. A general statement of the need for perspective is made by Professor Franklin H. Giddings, of Columbia University, as Chapter I. This is followed by two other introductory statements: Professor Brightman gives a brief account of the pre-scientific conceptions of the universe—as these take form in the creation epics. Following this is a characterization of the scientific as distinguished from the pre-scientific approach. Chapters written by specialized scientists make up the main body of the text. The several chapters are arranged in three groups: those which deal with the universe as non-living matter (Part Two); those which deal with life, and the contributions of nature to the solution of life's problems before the advent of man (Part Three); and those which deal with man and his contributions (Part Four).

From necessity this book is the product of collaboration. The central, uniting theme is man's outlook on life—the universe as seen from different angles by men of science. Therefore, each contributor has focused his attention on a common objective. The final task of the editor has been to make the contributions of the several scientific specialists dovetail, one into the other—to the end that all the contributions taken together present to the mind of the reader a larger conception of the universe than could be obtained from any included group of subjects treated. The chapters are so subdivided that the pre-scientific conceptions come first. Following this are the conceptions of the related descriptive and interpretative sciences.

Whatever defects there may be—in the general design, in the arrangement of subject matter, in the emphasis given to conclusions reached and principles discussed—these are to be assigned to the editor. Each specialist as contributor, however, has been

generous enough to give of his valuable time whatever was necessary to prepare original manuscripts submitted to the editor and to go over the text in final form with a view to assuming responsibility for approval of the substance of the chapter or chapters with which his name is associated.

To every contributor the thanks of the editor and the publishers are cordially extended; for to them as specialists is to be attributed whatever value this volume may have. It is offered as an aid to educators in their endeavors to bring the diverging lines of science within the mental reach of a single individual—the reader.

Special mention is due to Professor Edgar S. Brightman for advice in developing and arranging the outline of chapters and the subject matter herein discussed; to Doctor Wayland F. Vaughan and Mr. J. Rea Butler for their criticism in reading manuscripts; to the Reverend Ray Allison Heaps, and Lindsay Cleveland for assistance in the location and selection of the illustrations; and to Mr. Carl Ellsworth Smith for help in many ways, but especially for seeing the volume through the press in my absence.

FREDERICK A. CLEVELAND

Norwood, Mass.,  
April 30, 1929.

## ACKNOWLEDGMENTS

It is with pleasure that acknowledgment is made to the following publishers for their kind permission to use the illustrations listed.

D. APPLETON & COMPANY: Figures 3, 4, 6, 7, 10, 13 (from *From Myth to Reason*, Riley, 1926); Figures 67, 79 (from *Animal Life*, Jordan and Kellogg, 1900); Figures 117, 118 (from *Psychology of Human Society*, Ellwood, 1923).

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A. G. SEILER COMPANY: Figure 103 (from *Elements of Psychology*, Thorndike, 1907).

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PART ONE  
INTRODUCTORY



## CHAPTER I

### THE PRESENT-DAY NEED FOR PERSPECTIVE \*

**Man's Quest for Knowledge.** "The proper study of mankind" has become a more arduous undertaking than it was when the intelligent Mr. Alexander Pope addressed himself to it in 1733; and one could hardly obtain a better notion of the quality and extent of change since that time than by sitting down with the present volume in one hand, and a copy of "The Essay on Man" in the other and comparing them. Pope was a keen observer of human behavior; he was adept in satirizing human insincerities and follies. But of what we should today call scientific knowledge of mankind neither he nor his contemporaries had enough to inventory. It hardly existed. Attempts to account for man and to explain him were theological, metaphysical, and for the present purpose, futile. Today our verified, that is, our "checked up" knowledge of the origin and constitution of man—of his place in the universe, and of the nature of that place—is appalling in extent and bewildering in detail. No living person can master it all. What, then, shall we do? Or shall most of us indolently do nothing?

**A Problem of Democracy.** It happens that we must do something, or try to, because the human problem of living together, itself, has changed. It is no longer the problem of the head of the family, or of the council of clan or tribe. It is no longer the

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problem of a few strong men—demigod, monarch, or ruling class. It has become the problem of democracy; and democracy is commonly understood to be a way of living together in which everybody is expected to think, to say something, and to do something about everything. In other words, everybody is expected to consider, to choose between alternatives, to reach conclusions, to vote. And no one can make choices or vote intelligently unless he has knowledge on the subject to be thought about. Leadership is no longer only a matter of directing cooperative action; for in a democracy the object of the action must be approved. There must be leadership directed toward organizing the thinking, the sentiments, the will of the people before authority for action is forthcoming. There must be organized intelligence.

**Two Views of Democracy.** It is true that we distinguish between democracy which attempts to govern, and democracy which is content to have a mind—think, feel, will. We must distinguish between a democracy which does everything and a democracy which is sovereign—exercises final approval and disapproval. We must distinguish between a democracy which impulsively responds to leadership, and one in which public opinion is made the final arbiter when questions are raised among those who are trusted with leadership. We must distinguish between direct and representative democracy. The one kind undertakes to deliberate, to legislate, even to administer, as a committee of the whole people. The other kind undertakes to be intelligent in the choice of its representatives, and in approval or disapproval of their acts—to create and empower legislative bodies and responsible ministries. The pot and kettle partisans of these two kinds of democracies call each other black; and black they are bound to be in any case, if both are ignorant and content to be so. Theoretically, democracy might be a government of the people, for the people, and by persons chosen because of their known competence to serve—persons empowered and held to account by the people. It is, however, a case of catching your bird by putting salt on his tail. How shall the ignorant pick the competent, or desire to? So our modern democracies are confronted by a real danger—the danger suggested by the ancient wisdom: “For lack of knowledge the people perish.”

**What Is Knowledge?** What, then, do we mean by knowledge? Do we mean that our salvation depends on each person's being cyclopaedic—knowing everything? Do we mean that each must possess himself completely of the body of ascertained facts about his environment—the whole fund of information developed and transmitted, whether as race culture or as data of science? In these days of individual freedom and high specialization this is obviously impossible. If this is the knowledge on which the safety and sanity of democracy depend, then, indeed, democracy is doomed; the ascertained facts about life and substance have long since become too voluminous; knowledge has already outgrown the capability of the human mind to comprehend it.

**Seeing Things in Perspective.** The inescapable, practical problem which has confronted man since he ate of the tree of knowledge is the problem of living together. Humans have developed capability for arresting motor impulses while considering states of mind and alternatives. Humans have developed capability for solving problems in imagination and considering imagined results before throwing the motor mechanism into gear. Humans have developed capability for considering alternatives as these present themselves to the imagination, and discussing them in groups—in order that they may avail themselves of reflection based on the experiences of the many. Thereby, they make co-operation more effective.

**The Problem of Thinking, Feeling, and Willing Together.** As intelligent beings, humans have learned that, if and when they live together, they must think together, and feel together. Our training must be such as will enable us to harmonize and synchronize thought, feeling, will, and action. Our information must be such as will enable us to turn the forces of nature and human nature to account for common ends—purposeful and useful. On this our fate, and the fate of mankind depends. The problem of living together (thinking together, feeling together, willing and acting together) lays on us ever-increasing demands. For each of us, our world is getting larger and more intricate—more perplexingly entangled in its human relations. Instead of living together in small exclusive groups controlled by custom, social living has grown bewilderingly complex. Our interests have become

infinitely varied. Our group arrangements intertwine and overlap. Smaller group interests and activities are interrelated with each other, and with the interests and activities of larger group interests and activities. Each of these varying interests demands loyalty; and all loyalties must be harmonized. As a whole, the scheme of living comprehends the related activities of millions of human beings. In its largest aspects, it includes the interrelated activities of all thinking, feeling, forceful individuals, each giving expression in action to an urge to achieve. Out of the give-and-take experiences of living, a marvelous social mechanism has been evolved. Each has many associations. Every specialized association is based on a specialized interest. And every specialized interest has to do with some new and differing aspect of environment—natural or social. In this situation is found our increasing need for perspective. Without perspective we cannot be intelligent in our thinking about either nature or human nature. Awareness of the need for perspective is the meaning of that longing in man which has made him “monarch” of all he surveys.

**What Is Meant by Intelligence.** By intelligence we mean the ability of the individual not only *to think, to feel, and to reason*, but to think, feel, and reason with others as an integral part of an ever-widening and more complex scheme of living together. It is the ability to grasp mentally and to meet practically an existing or imagined future situation as a whole. We solve the problem of living, of living together, as we answer the question: How may our thinking together and feeling together be true to nature and human nature? The world is man’s oyster. How can he open it? It can be done only by working together. This means that our feelings as well as our thinking must be true. How may our thinking and feeling be true to the order of the universe? Mere awareness of a multitude of things is not enough. We must have understanding. We must relate all our contacts, all our experiences, all the tested, tried-out data that constitute our awareness of persons and things. These data must be related to common categories—to concepts and conclusions by use of which the universe (nature and human nature) as a chaos may be set in order in our minds. These categories of thought are the truths by which our lives must be guided.

**How Shall Our Thoughts Be Guided?** The question which teachers and learners must answer is: How shall our thinking and feelings be guided? John Dewey tells us, in his suggestive volume written for teachers and students under the title "How We Think," that all reflective reasoning rests on "beliefs." These beliefs may be false; or they may be based on evidence—they may be conclusions tested and tried. William James and other psychologists point to the fact that most of our *beliefs* (the main premises of our reasoning about life) are generalizations which we have accepted "on authority"—accepted without question because of the confidence we have in parents, pastors, teachers, leaders, and other persons whom we trust. The principles which guide them in their reasoning, the beliefs which serve them, we accept as our guides to group thinking. If, therefore, these do not stand the test of experience, our thoughts and energies will be misdirected. Instead of our thinking being an aid to adjustment, it might be less useful and effective than the instinct of the bee or the habit of a member of a herd.

**"Beliefs" and Intelligence.** That which serves each and all of us as knowledge is a complex of "beliefs"—a philosophy of life. Our need for perspective is our need for seeing things in relation. Whether we are wise or foolish depends on the vision we have gleaned by processes of reasoning—the premises for which are the conclusions reached by men trained in research. Men had perspective before the advent of science, but it was not true. True perspective means picturing the universe as it is. In our complex living arrangements, true perspective is the vision of the sciences in their relation to one another. This vision may be vague and never quite complete. But it need not be at variance with ascertained or ascertainable facts.

**The Vision That Serves as Knowledge.** The vision that serves as knowledge is that which stands the test of experience in our broader, more complex scheme of living. No man can afford to hold to a belief which leads him up a blind alley simply because, in quite different circumstances, it proved useful to a past generation. Such a belief, if persisted in, must defeat the biological purpose of intelligence, viz., to enable the organism as posses-

sor to adapt itself to environment. The human species possesses intelligence in a higher degree than any other. But woe to the individual or the group that imagines vain things. To imagine a universe which does not exist creates dilemmas instead of resolving them. Such beliefs close instead of open the way to adaptations that are useful and beneficial.

**The Test of Beliefs as Truths.** The conclusions which we accept as fundamental beliefs must of necessity be such that they leave the way open to a larger view, arrived at by reasoning about every fact to be reckoned with. No pertinent fact can be overlooked if we are to grow in wisdom, the grace of God, the goodwill of mankind. Only those beliefs can continue to serve us which, when tried, are not found wanting. Our understanding of the universe is largely a product of social living. Our philosophy of life, like our scheme of living, is a social heritage. No man can gain a true vision except by the process of social interstimulation and response. Broadmindedness is a phase of social-mindedness. Perspective comes through contact with one's fellows. An intelligent individual can master one science, or a division of one, and, in doing it, becomes acquainted with scientific method. Then, by another procedure, he can inform himself of the premises and major conclusions of many other sciences. This is wisdom.

**What Beliefs We May Accept on Authority.** To grow in wisdom we must take much of our knowledge on trust. But our trust must be not in persons who offer as truth fabrics woven from the cobwebs of thought gathered from the garrets of mystics and soothsayers who pose as spiritual leaders. Our trust must be in those who, at great pains, have come to know what the facts are with which we have to deal when attempting to solve our problems. Our trust must be in the masters—each in his own field. The truths we live by must be taken from those who have made themselves authorities—each in his own science. The point at which each must watch his step is where he chooses the servants he will employ—masters that he will follow. If he picks charlatans, his state of pseudo-knowledge is worse than his antecedent state of innocent ignorance.

**Scientific Beliefs.** It were better, if he were like the ant or the bovine, that he act in response to innate urges without thinking or knowing at all. To avoid the peril of fallacy, man, as an intelligence-guided being, must rely on his own painfully acquired acquaintance with methods by which his beliefs are tested. He knows, or should know, that the one thing that he must be sure of is the validity of the methods used by the investigators whose statements he would accept. And here again, wisdom is largely a matter of social living—learning through group experiences which we may trust. It is truth (not tradition or custom, or institutions or laws, or prejudices purveyed by a class) which will make us free—wisdom, individual and group wisdom—the tried-out and proved conclusions of science.

**The Present-Day Tragedy of Education.** A present-day tragedy of education is the boundless misinformation brought every year by tens of thousands of bachelors of arts and of science to universities where higher degrees are sought. In good faith they have been told to read, even to “learn,” in undergraduate work, falsehoods and rubbish from tenth-rate textbooks written (and in the colleges they may be taught) by “professors” incapable of discriminating between a Robert Andrews Millikan or an Edmund B. Wilson, and an educational delicatessen vendor vouched for by civil and theological politicians as “safe.” It is hoped and believed that these chapters will give effective first aid to many unhappy victims of ptomaine, which has been fed to them in mental foods too long kept or unscrupulously compounded.

**The Kind of Perspective That Is Needed.** Perspective is needed today not only in our outlook upon knowledge, but also in our survey of the incidences of knowledge and of its utilization. Upon whom does knowledge descend? How is knowledge distributed? Democracy boasts that it offers education to everybody who will accept it. Yes, but what education? Not the same for all. At the same cost to the taxpayer (for the same salaries to teachers) some pupils, including grown-ups, get education that enlightens by encouraging the acquisition of accurate information; that develops initiative and self-reliance; that fosters tolerance and understanding. Other pupils, young and old, get an education in childish nonsense, quackery, dogmatism, bigotry,

truculence, and all uncharitableness. We need a true perspective of the relative extent, and of the distribution of these two educations. The distribution is fateful for the future of democracy.

**Our Standards of Valuation.** The arts, like the sciences, are highly specialized. The all-round mechanic has disappeared. "Master of Arts" has become a term of little meaning. The Leonardo da Vincis are as extinct as the Francis Bacons. We must cultivate appreciation of one another's interests and achievements, and respect for performances which are beyond our own talents, or are unrelated to them. If we are to grow in wisdom and in grace we must learn what standards for judgment are tested and true. And we must learn how to apply these to unsolved problems as they arise—perhaps in unknown fields. To develop capacity for appreciation—ability to know what is true and what is not, and to feel the pleasure of such comprehensions—is the highest aim of education. This is the only true perspective; any other vision of life and its problems is illusory.

**Lights that Save Us from Wandering on False Trails.** How shall we get perspective in our view of the world, of man, of knowledge, of education, of the arts? How shall our picture of the thing as we see it be made true to the eye of "the god of things as they are"? There is only one way. No individual can think far or get far from the checked-up facts of personal experience. We must learn to think in each other's terms—think together. We cannot all be physicists, or all biologists, or all psychologists, because we cannot master so much material, so many methods. But we can and we must learn to think as the genuine master in each science thinks about his methods and his material. There are brain paths along which our thought may travel when we attempt to solve our problems—if our education has not been neglected or perverted. We can and we must learn to think about energies and mechanisms as the physicist thinks about them; about organisms as the biologist thinks about them; about behavior (controlled by reflexes, habits, intelligence) as the psychologist thinks about it; about the origin, development, and potentialities of man as the anthropologist, the archeologist, the historian, and the sociologist think about them. So thinking, we shall get our true perspective. These are the lights that will

save us from false prophets and disastrous wandering on false trails. And so basing our transmitted culture, each generation may make its contributions to the next—striving as it must to make its adjustments by bringing to bear on each problem an ever-increasing fund of knowledge.

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17. How may we come to have trustworthy standards for judgment?

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## CHAPTER II

### PRE-SCIENTIFIC CONCEPTIONS OF THE UNIVERSE —COSMOLOGY AND THE CREATION EPICS \*

**Chaos and Cosmos.** Civilized man, when he sees an object, always sees more than meets his eye. If he looks at a chair, he sees more than its size, shape, and color; he sees it also as something-to-be-sat-in—as something more or less like other chairs but quite different from automobiles. Civilized man can hardly imagine what it would be to see a chair as the savage or the baby sees it—without the slightest idea of its meaning or use. If we are to understand how different the world seems to us from what it seemed to the primitive mind—what has been achieved in the interpretation of experience—we must try to think ourselves back into that state with which both the race and the individual begin. The various pictures which make up the stream of our memories, our imaginings and conscious thoughts, are our world. What passed through the mind before the days of science was a jumble almost wholly uninterpreted; the things looked at were almost wholly unrelated. Both to the savage and the child, the world is a “blooming, buzzing confusion.” The “stream of consciousness” (to quote James again) is a moving picture without captions and without “continuity.”

**The Pictured Order of the Universe a Catalogue of Experiences.** Becoming intelligent is a process of putting things in order in one's mind. The order as we picture it may not be true. It may be made up of imaginings not verified. It may be quite out of perspective. The conclusions drawn may be quite

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false. The imagined order may be a bad arrangement that gets us into trouble. But arrange things in our minds we must; otherwise the world and our experiences in it are a chaos. Not only do those who cannot see things in perspective (the savage and the infant) see things as chaos, but so do all of us see a large part of what is sensed but not analyzed. True, the civilized adult habitually strives to interpret the chaos around him in terms of meaning; but it is also true that no one can boast of any starting point for order other than the chaotic data of immediate experience.

**Thinking as Order.** Thinking begins, then, with our being made aware (conscious) of the separateness of things brought to attention through the senses. These objects are related to each other in our minds when we come to associate them with our interests. Thus, experiences remembered and things immediately sensed come to arrange themselves. And we come to have an idea of an existing order; the world around us comes to be ordered in our minds. Thinking is a process by which man interprets the meaning of things. And this soon takes the form of beliefs—i.e., conclusions in which we have confidence and therefore rely on to guide us in our further thinking. In a civilized group the things believed in (or the interpretations in which we come to have confidence) are relied on as a guide to conduct; so that by reason of the inborn curiosity of a child, and the tendency to imitate, the babe of civilized parents comes to acquire habits of thinking based on the experiences of the race.

**Experience as Transformed by Thought.** No human being who develops mentally can remain at the stage in which he does not think of the meaning of things. He cannot simply sense things. The very process of thinking is one of correlation. The world cannot long remain, for anyone, a mere chaos. Experience accumulates meanings. Just as every word we read stands for a system of ideas, thus enabling us to pass beyond the word and grasp the suggested ideas, so every item of immediate experience has some significance for our interpretation of the scheme of things we come to know as the universe. Every one of our assertions about objects which lie beyond present experience, or

about laws or general truths, is an attempt to answer the question, "What does this chaos of immediate experience mean?"

**Our Conception of the Physical Universe.** There is an interesting analogy between the psychological fact which we are describing and man's view of how the physical universe came to be what it is or was. The original state of affairs, according to the writer of the first chapter of Genesis, was "tohu wa bohu"—"without form and void." According to Herbert Spencer it was "an indefinite, incoherent homogeneity." According to others it was the fire-mist. According to all, the starting point of nature is confusion and chaos; but in the process of things there is something that introduces order into confusion and brings cosmos out of chaos. The tendency both of thought and of reality is to develop order. The aim of all science is to discover the various types and laws of order.

**Cosmology: Theory of Universal Order.** The mind of man does not rest with the discovery of a law here and a law there; man constantly inquires into the relations of the different laws and orders. Both curiosity and logical necessity drive him to such inquiries. All of our interpretations are related to each other by virtue of their being thought by the same mind and by virtue of their reference to the same universe. All orders are relative to one system of order; all microcosms or minor systems are members of one macrocosm or great system; and we come to think of all parts as belonging in some way to the one whole.

**Cosmogony and Cosmography.** The greatest minds of the race have been concerned with the question: "What is the universal order?" The attempt to answer this question is our *cosmology*, our theory of the cosmos as a whole. Our conception of the beginning of things is called *cosmogony*; our description of the system of worlds, *cosmography*. The Greek word "kosmos," from which these English words are derived, means both beauty and order, as well as universe. Our word "cosmos," therefore, reflects the Greek conviction that every reality is a system or part of a system of ordered beauty.

Philosophers have different opinions about cosmology. But no human being of advanced intelligence—be he philosophical

or unphilosophical in the technical sense—can refrain from forming some sort of hypothesis about the universe and universal order. These cosmologies reflect the visions of order seen by individuals and peoples of advanced intelligence. Our own cosmology or world view—what the Germans call *Weltanschauung*—colors our present-day interpretations of what we see and know as truly as our concrete and scientific knowledge of the parts contributes to our view of the whole. Indeed, no part of anything can be understood when considered in complete separation from the whole to which it belongs. This applies to the parts as related to the whole of experience. Thus our knowledge of perceived minor orders and our conception of the order of the universe as a whole grow together. Knowledge as ordered thought grows all over, like an organism; it is not a mere addition of item to item.

**Man's Progress in Achieving a Cosmology.** Man starts with no information about his origin or destiny; no knowledge of the history or shape of his planet; no conception of astronomical distances; no understanding of the processes of life; in short, no cosmogony or cosmology. His first steps out of ignorance are vague guesses—romantic imaginings, mythologies. But these vague guesses, imaginings, mythologies are an advance; for they represent the belief that there is order and explanation, even though they fail to arrive at the true order. In fact, we may say that at the time and in the circumstances they were true; for truth itself has come to be thought of as a conception that rings true to all known experiences. As the centuries go by, man accumulates observations of fact, verifies his hypotheses by experience and reason, and evolves higher and more rational types of cosmology. There is no reason to suppose that this process will ever come to an end. Even though some features of cosmology may remain relatively constant, there will never cease to be reinterpretation of the detailed structure of universal order.

**Primitive Cosmologies.** Primitive man viewed the world solely from the standpoint of his practical needs. For him, what “worked” was true; he was a pragmatist before pragmatism. Intellectual curiosity from the standpoint of pure theory was

unknown to him. He was concerned only with the effect which the world about him would have on his life and death, his food and clothing, his marriage and children. He perceived that nature does not distribute its benefits evenly, but that some persons have far more prosperity and success than others. He therefore



Figure 1. The Creation of Adam. (From the *Nuremberg Chronicle*. Courtesy of the Harvard College Library.)

believed that the source of all unusual welfare and excellence was a mysterious power which we should call supernatural (although the concepts of nature and of supernature were equally foreign to primitive man). The Melanesians called this power *Mana*, and a similar conception may be traced among most primitive peoples.

The conception of the universe as a source of mysterious power developed along with the belief that in everything that lives there is a life-power akin to the soul of man (animism) which is not necessarily bound to its body but may leave it and travel abroad



Figure 2. The Creation of Eve. (From the *Nuremberg Chronicle*. Courtesy of the Harvard College Library.)

(spiritism). Attempts to control and compel the working of *Mana* were the beginnings of magic; friendly relations with the *Mana* of spirits of superhuman order were the first stages of religion.

**Ancient Oriental Cosmologies.** As civilization developed, man paid more heed to the uniformities of actual experience. Changes of the seasons and the heavenly bodies were observed; the laws of good health were gradually noted; the principles of physics, if not accurately formulated, were utilized in architecture and other undertakings; man explored his world and the body of orderly knowledge grew. Social life also developed, and more complicated and effective social institutions and customs took the place of the primitive clan. For ancient man, religious beliefs

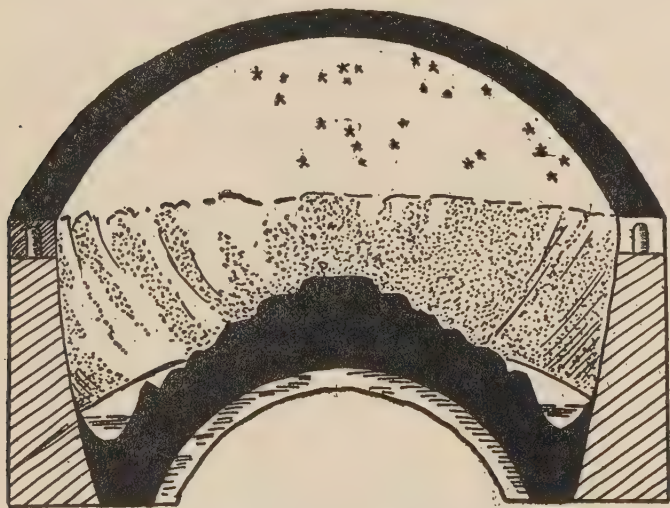


Figure 3. Babylonian Conception of the World, created by the god Marduk. The sun returned to the east each night through the tunnel around the horizon.

were inseparable from the rest of his culture. Growing observation and creative imagination conspired to mold more and more grandiose cosmologies. Men gave expression to their beliefs about the origin and development of the universe in countless myths and epics.

Probably the most influential ancient cosmologies are those which, in their main outlines, originated in Babylonia and were given a monotheistic interpretation among the Hebrews. These cosmologies, preserved in creation epics, aim to give some account of the ordered universe (cosmology) and its origin (cosmogony). They usually regard water as the most ancient principle of things,

perhaps because of the importance of the annual inundations of Babylonia by the Tigris and Euphrates rivers. Now water manifests itself to man in two ways: as tempestuous and destructive on the one hand and as law-abiding and benevolent on the other. The hideous dragon Tiamat was supposed to represent its destructive aspect and the great deep; Apsu, its calm, benevolence, and law. Tiamat—wild, watery chaos—was the oldest power in the universe; or, according to some, coeternal with Apsu. The relation of the gods to these primeval powers was variously stated.



Figure 4. Marduk Kills Tiamat.

For our purpose, the important fact is the Babylonian belief that the dragon Tiamat, the principle of chaos and disorder, had to be overcome before creation and development could proceed. The god Merodach (Marduk, *cf.* the Biblical Mordecai) fought with the dragon, cut Tiamat in two, and then stretched the sky across one half and put the other half under the earth and sea. After this heroic struggle came creation. Plants, animals, and man were brought into being. Thus did the Babylonians explain their experiences of nature; order, they held, prevails over confusion.

A consideration of this myth clarifies numerous expressions in the familiar Hebrew cosmogony of Genesis, Chapter I. The

Hebrew word for "the deep," in verse 2, is "T'hom," which is the Hebrew equivalent for Tiamat. As in Babylonia, water is the original state of affairs, and chaos is conquered by dividing "the waters which were under the firmament from the waters which were above the firmament." The essential difference between



Figure 5. The Universe of the Hebrews

the two conceptions lies in the clear-cut monotheism of the Hebraic as distinguished from the polytheism of the Babylonian view.

**Greek Cosmologies.** Similar ideas underlie the Greek myths. As in the Hebrew story darkness was upon the face of T'hom, so in the Homeric writings (instead of the hideous dragon) the goddess Night lay back of all else in the universe. Further

analogy is found in the belief that the development of things began from water. Oceanus was father of all the gods; the original mother was Tethys, probably the earth. Hesiod expressed things differently. Chaos for him comes first, then the various gods; but Hesiod seems to have little, if any, idea of causal relations in the development. In Pherecydes (6th century B.C.), there arises in Greek speculation the belief that Zeus, conceived as spiritual power, is the original cosmic principle; but even within the universe thus conceived, Pherecydes pictures a struggle in which Cronos, the principle of order, defeats the dragon Ophioneus, the principle of chaos, before cosmic process *can* go on. Many other cosmologies were devised. The Orphics, beginning with a cosmology substantially that of Homer, later arrived at the belief that Time, Aether, and Chaos were the ultimate principles. In these and other cosmologies one finds in many guises the conflict between Chaos and Cosmos in which Cosmos wins the victory.

**Main Motifs of the Ancient Cosmologies.** The ancient cosmologies were based on a few broad, general observations, elaborated by the myth-making fancy, and intended to show that the scheme of things is friendly to human interests. They were, in short, not scientific or theoretical, but practical. Further, they were largely constructed by men concerned about religion, in order to find a place for the gods or god, and for religious practices. To a certain extent, also, they were used to support social and moral institutions. The main motifs of the ancient cosmologies may, therefore, be said to be the practical, the religious, and the moral.

**Main Motifs of Modern Cosmologies.** In our brief survey of ancient cosmologies, we have purposely omitted the great constructions of the Greek philosophers, because in them there is to be found the dawn of the truly modern spirit. It was the rediscovery of Greek antiquity that fertilized the modern thought-world and produced the Renaissance.

Modern attempts to discover the laws of cosmic order are characterized by at least four specific traits: (1) There are those attempts based on observation of fact and generalization from the facts, rather than on practical or religious interests (this, however, does not imply that modern thought is impractical or

irreligious—it means rather that modern thought tends to base its practice and its religion on the facts rather than twisting the facts to suit practical and religious ends); (2) there are those attempts marked by the use of stringent logical methods, both deductive and inductive—such methods in the observation of natural phenomena requiring the formulation of laws in mathematical terms; (3) as related to, and derived from, the use of mathematics in physical science, we have those cosmological conceptions, mechanistic in essential features, whose first great protagonist was Democritus, the Greek; (4) modern cosmologies—from Thales to Hegel, as well as from Darwin to the present—dominated by the idea of evolution or development. It is only in this evolutionary or developmental aspect of the primitive and the more recent cosmologies that any noteworthy similarity can be traced between the modern and the ancient mind; for both ancients and moderns, in a large way, believe that some sort of continuous development may be discovered in the order of things.

**Typical Tendencies in Contemporary Cosmology.** When we speak of contemporary cosmology, it is not to be supposed that there is a clear and unified view of the cosmos on which all competent thinkers agree. Such a situation will never obtain until all truth is known. There is difference about the importance of various types of facts, and also about the significant relations among the facts. But, after all, the differences of opinion among philosophers are not a ground for skepticism, since every thinker is doubtless dwelling on certain real aspects of our experience. The truth will lie with that view which includes most comprehensively the truth in all views; or, to state it otherwise, with that view which sees most completely all orders of facts and relations.

There are five tendencies in contemporary cosmology which are worthy of especial consideration as shedding light on types of order to be found in the cosmos as conceived by thinking men. These tendencies have been called by names which mean very little to the average reader or untechnical student, namely, the analytic, the naturalistic, the evolutionary, the idealistic, and the axiological. They may be briefly distinguished as follows:

1. The analytic tendency is one which, as the name indicates, seeks to explain the cosmos as a whole in terms of the relations

among the ultimate parts into which it may be analyzed, such as atoms, electrons, or even points in space and instants in time. In contemporary thought, the analytic neo-realists, notably R. B. Perry and B. Russell, build their cosmologies on this sort of foundation.

2. The naturalistic tendency regards space and time as the ultimate realities. This cosmological conception is closely related to the third, which follows.

3. The evolutionary tendency emphasizes the facts of development, novelty, and life as most characteristic of cosmic order. Recent writers who have emphasized various aspects of both the naturalistic and the evolutionary points of view are John Dewey, R. W. Sellars, and S. Alexander. An evolutionary but less naturalistic cosmology is developed by Bergson and C. L. Morgan.

4. Idealistic thought has found the unifying principle of cosmic order in mind and its ideas, and comes to the conclusion that reality is a mind or a society of minds. For this view, space, time and evolution are best understood as activities of cosmic mind. Pringle-Pattison, J. Ward, B. P. Bowne, J. Royce, and M. W. Calkins are exponents of this sort of cosmology.

5. The name, axiological, is not even suggestive of an idea to the layman; but it has recently been used in philosophical discussion to describe the problem of value. Any cosmology, it is felt by many thinkers, must not only account for the types of order revealed in sense-experience, but must also take cognizance of such concepts as truth, goodness, beauty, holiness, and the like, as criteria for the interpretation of value experience. There is great difference of opinion about the cosmic status of values; but all are agreed that thought must give an account of value-patterns as well as of physical things and biological organisms. Meinong, Ehrenfels, Windelband, Rickert, Sorley, Urban, Perry, and others have made contributions to axiology.

**Order as the First Law, Both of Mind and of Nature.** Thus briefly sketched, our survey of cosmological thought has shown us that, from early times down to the present, man has been engaged in the enterprise of ordering the confusion in which he found himself—he has been engaged in the process of interpreting the meaning of things. The basis for this enterprise in most

ancient times was a very narrow one. Man's knowledge of natural facts was limited, but his fancy was unbridled. As civilization has developed, man has tamed his fancy, and has enlarged the scope of his observations of fact and his knowledge of law, or the foreseeable and dependable tendencies in matter, force, and being. The fact that the early cosmological conceptions were primitive does not mean that they should be lightly regarded. They were fundamental. They were first steps in an evolutionary process. Thus beginning our inquiry into culture, the successive stages in the evolution of human intelligence may well be thought of as progressive advances in the ordering of experience to the end that man may act with truer perspective in making his day-to-day adjustments.

**The Basic Fact of Intelligence.** The basic fact of all intelligence is that order exists; that it is discoverable; and, to the extent that thinking has served a useful purpose, it is helping man to solve his problem of living. We may say with Pope that "Order is Heaven's first law." But whatever may be the case in "Heaven," it is certain that the human mind is an instrument for ordering experience on earth. Thereby, man has been able to see things—to see things that to all other beings are hidden. Thus by ordering things, and seeing through things, man has made himself the master.

**Cosmic Order the Quest of the Human Mind.** No active mind is ever content to take things as they come. The chaos of immediate sense-experience is always examined, analyzed and related to other experience—in short, ordered with more or less success. Order is the first law of every mind that is conscious of its own function. Most normal minds carry their confidence in the principle of order still further and regard the cosmos as an orderly structure. It is true that no human mind is completely ordered, and also that the order of nature is imperfectly known. But acceptance of the hypothesis that mind ought to be true to its orderly bent and that nature is a system where rational order may be found, lies at the basis of all the sciences and of all human progress. Yet physicists are now beginning to doubt whether the familiar principles of physical order apply to the microscopic

structure of things. In its search for order, then, the mind should cautiously beware of hasty generalizations.

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## CHAPTER III

### SCIENCE, EDUCATION, AND CIVILIZATION \*

**Science a Mental Attitude and a Method.** As the purpose of this volume is to bring into perspective the contributions of a vast army of scientists, each working in his own field, and to set the mental pictures called scientific over against those called pre-scientific and unscientific—it seems fitting at this point to say something about the meaning of science, and its import to education and civilization. Science, as the word is commonly used, means organized, verified knowledge—as distinguished from unorganized and unverified observations or conclusions. The difference between science and non-science fundamentally is a matter both of mental *attitude* and of mental procedure, or *method*. The mental attitude which interests us here (whether scientific or unscientific) has reference to *beliefs*. The difference in attitudes is that the non-scientific mind accepts beliefs as absolute; the scientific mind takes a questioning attitude toward all beliefs. The scientific method is a procedure adopted, or a mental pattern developed, for testing the truth of beliefs—the first essential of which is to verify the data that are organized into beliefs by processes of reasoning.

**Civilization.** Orientation means seeing things in perspective. The perspective which has greatest value is the relation of particular observations or experiences to that larger whole of experience called civilization. Seeing any particular subject in perspective requires that we also get before us a notion of what is meant by civilization. In other words, we are dealing with the application of science to what are conceived of as cultural objectives. We may begin with the word *civilization*. This comes from the same root as citizen. Its etymology carries the meaning, pertaining to a citizen. What is symbolized by the word is the idea that civilization is not an individual matter; that it is a

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\* By Frederick A. Cleveland.

culture evolved by a highly organized group to which the citizen belongs, or of which he is a part—a city or a state. As the word is used in the literature of science, civilization means a broad, inclusive, cultural scheme. The content is suggested by Wissler, an outstanding authority on primitive culture. He analyzes the content and sets up the structure of what is universal in all cultures. He calls this “The Universal Pattern.” A modification of his inclusions, with others, is shown below.

### **Inclusions of a Cultural Scheme.**

1. Languages, written and spoken—systems of symbols used for communicating states of mind by use of words and gestures.
2. Conventions for expressing ideals—art, carving, painting, drawing, music, etc.
3. Systems of beliefs—religious and secular—theology and scientific knowledge.
4. Cultural procedures—religious practices and educational techniques.
5. Traits developed in dealings with physical environment:  
(a) food habits; (b) dress; (c) shelter; (d) transportation and travel; (e) utensils, tools, etc.; (f) weapons; (g) occupations and industries.
6. Institutions for determining what persons may dominate the instrumentalities of achievement—property.
7. Family and social systems: (a) forms of marriage; (b) methods of reckoning relationship; (c) inheritances; (d) customs determining social status and control; (e) sports and games.
8. Government: (a) political forms; (b) judicial and legal procedures.
9. Organization and practices in waging war.

**Group Cultural Patterns.** The several elements above listed are called traits. Each of the traits is a highly organized complex. When woven together into a group pattern this higher complex gives to a people or tribe or other group its characteristic culture—its civilization. Thus, applying the word culture to a particular group, it is customary to speak of Oriental or Occidental culture

or civilization. Thereby, attention is directed to the cultures that are broadly characteristic of Eastern or Western peoples. More narrowly used, we speak of culture or civilization in terms of race—as Egyptian, Assyrian, Greek, or American. And still more narrowly the culture of an age or the civilization of a people is described in terms of industrial technique or equipment—as is suggested when we speak of the civilization of the Stone Age, of the Age of Steam or Electricity. And so, too, culture is discussed generally as having a subjective as well as an objective aspect, as is considered in Chapter XXVII.

**Education the Development of Individual Cultural Patterns.** Concretely, what is meant by the subjective aspect of culture or civilization is that which is peculiar to the mind of the individual. This individual cultural pattern is called personality (see Chapter XXVIII). On the other hand, the group cultural scheme (the group traits as outlined above) is objective; it is external to the individual. The attitude of the individual determines his conscious behavior—his conscious acts, his dealings with both social and non-social environment. The scientific attitude, therefore, has a very direct bearing on community life. And the community has a very direct interest in imparting it. Whether the attitude be scientific or unscientific depends on the kind of social pressure brought to bear on the development of the ideal or dominant self of each person—his characteristic actions and reactions. The social or environmental pressure which in the main determines attitude is education—in its broadest sense including all forms of cultural activities. In any case, both personality (the subjective pattern) and civilization (the group pattern which is objective to the individual) are to be thought of as products of growth—a subject which is discussed in a later chapter. This brings us to the point of present interest—the relation of science to cultural growth.

**The Conditions Which Make for Growth.** The idea of growth may best be stated by way of analogy. The biologist tells us that growth is the result of pressure, internal to the structure, brought to bear or focused at a point where tissue is plastic. This general idea of the conditions which make for physical growth is used by the psychologist and the sociologist to explain

mental and social organization and expansion. And it is this idea to which emphasis is to be given when thinking about the social value of science. The attitude (called scientific) that makes for growth is set in opposition to another attitude (called unscientific) that stands in the way of progress—or else produces strains and stresses that make for disorder.

**Attitude Toward Beliefs.** We are here interested in the scientific attitude and procedure solely as they relate to beliefs. In Chapter I, Professor Giddings has laid emphasis on the importance of beliefs. Without beliefs as a part of our mental equipment we cannot think reflectively at all; they help us to analyze and interpret our experiences, and to correlate our own with the experiences of others. Whether true or untrue, beliefs underlie all thinking. Sooner or later we find that the beliefs which have been impressed on our minds by social pressures do not stand the test of criticism. Because of this fact some have gone so far as to assert that the human mind is, in the main, furnished with irrational beliefs—that is to say, irrational beliefs make up the principal part of our individual mental equipment. Whether our beliefs are rational or irrational depends not on whether they are true, but on our attitude toward them—and toward the culture of the group of which these beliefs form a part. If we have one attitude toward beliefs, our thinking, such as we may do, will be scientific. If we have another attitude toward beliefs, our thinking will be unscientific. Enlarging somewhat on this point without going too far into the scientific fields exploited later, something may be said about the rôle of reason, and the way reason is affected by the two attitudes.

**The Rôle of Reason.** We have said that growth is the result of internal pressure brought to bear on an organism where the tissue is plastic. The point of greatest plasticity in mental structure is where reason functions. Reason is distinguished from the automatic reflexes called instinct and habit. Reason is described as a mental reaction, the effect of which is to direct the pressures that modify the nervous structure. Or we may use a figure of speech and call reason the pilot—the adaptive agent that stands in between two automatic controlling mechanisms. On the one hand is the inborn mechanism called “instinct.” On the other hand is

the acquired mechanism called "habit." The important fact about both instinct and habit is that they are automatons, and therefore operate to control the motor activities (behavior) without thinking. They are prompt and effective so long as the thing to be done is to carry on in ways that are standardized. But when the automatic controls get the individual or group into trouble, reason comes to the rescue and changes the hook-up of the controlling mechanisms—as it does also when there is demand for expansion to accommodate the pressures that make for growth. The scientific attitude is one which gives to reason free play—the fullest possible opportunity to function in relation to each particular objective situation; for, if we assume that the premises for reasoning are always open to question, the mind is free to consider every imagined alternative as a way out when attempting to solve a problem.

**The Alternatives Presented When Considering Attitude—Prejudice or Open-Mindedness.** When the question of attitude is presented to reason there is only one answer. But how the mind works is largely determined by "the way we feel"—that is to say, by the emotional aspects or "feeling tones" associated with the instinctive and habitual trends, urges, or situations that serve as thought stimuli when attempting to find a way out of a dilemma. When experiences are organized by reason, they constitute beliefs or premises for further reasoning. The beliefs which serve us as premises may remain static (that is, unchanging) or they may be continuously readapted as experience broadens. In other words, beliefs may become stereotyped, or they may remain plastic—subject to modification when they are no longer helpful as a guide to judgment. The alternative presented to the individual and group is one of choice between a scientific or unscientific attitude. Shall the mind be kept open and plastic as the instrumentality of intelligent direction and control—and a procedure be adopted to test the truth of beliefs? Or shall the mind be closed—and a procedure be adopted for defending pre-existing beliefs as an abiding structure? An unscientific procedure is one which organizes the emotions around pre-existing beliefs for their defense. It is a question of scientific method on the one hand, or of a procedure in defense of prejudice

on the other. What is called "prejudice" is the product of an autocratic attitude toward beliefs. Properly used, it is a defense mechanism employed to protect the automatic controls (instinct and habit) from wanton or untutored attack and consequent impairment. Improperly used, it is an emotional state that is unfriendly to progressive adaptation. It is in this latter sense that prejudice is discussed as opposed to science.

**Prejudice as a Product of Unscientific Attitude.** Prejudice then, in the sense here used, consists of organized feeling tones associated in such a way with a belief that they will be automatically adhered to as final, absolute. To the unscientific person a belief is in the nature of a "vested interest." Prejudice is a device of a self-centered mind. Socialized prejudice is organized around beliefs that are the vested interest of a self-centered class. Prejudice, as organized hostility to change, is opposed to scientific reasoning; it gives a set to the mind opposed to the taking of evidence; it directs the deliberative processes to the "rationalizing" of custom or habit—for finding excuses for doing what is easiest. The distinction is between what Robinson calls a "good" reason and a "real" reason. Any suggestion that an existing belief is false is resented by the "rationalizing" individual. And detraction from custom, habit, or dogma is resisted, if need be, by force. This attitude, therefore, leads to inelasticity in the structure of mental organization. Unscientific beliefs clothed in and protected by prejudice make for mental atrophy or mental ossification.

**Open-Mindedness the Attitude Favorable to Growth.** On the other hand, open-mindedness is an attitude which invites challenge. The scientific method of procedure is a means of determining whether existing beliefs may still be used to advantage as guides to further reasoning. The scientific attitude is one which is organized around this procedure. The scientist has no feeling about a belief as such, except that it may be useful to him. It is a working hypothesis, to be discarded when a more useful tool may be found. The scientist has the same feeling about his system of beliefs that the carpenter has about his kit of tools. If he is a good carpenter he does not organize in his mind a prejudice against new inventions; he does not feel hostilely disposed toward anyone who suggests an improvement in the method

of making doors, or windows, or houses; he feels thankful for any suggestions that may lead him to a better understanding and a more effective solution of his problem.

Now, because thinking is a laborious process, and behavior which is automatic requires no thinking, the tendency is to rationalize existing beliefs rather than to reconstruct those working tools. Especially is this true of persons in positions of recognized leadership or authority. They usually have the same attitude toward change as have the owners of a monopoly, or a machine on which they are receiving royalties. It is their disposition to resist change or invention even at the risk of arousing strains in the group. Those who are content with the status quo, who find in it comfort or profit, turn a deaf ear to the voice of challenge and organize for defense. Thus, the existing structure is used to prevent progress.

**Relation of Beliefs to the Stabilization and Modification of Traits.** Just as culture is a composite of traits, so also is individual character. And as culture is changed by the pressures brought on the traits piecemeal (not on culture as a whole), so it is with character; the details of the individual cultural pattern must be considered. What vital forces will be brought to bear to prevent or produce change in the details of the pattern is largely determined by attitude. For example, when the attitude toward a particular language such as German or Italian is unscientific, the effect is to deprive the person or group which entertains it, of the benefits of cultural experiences which may be availed of in no other way. A prejudice against certain ideals which closes the mind to reflective reasoning about them, religious intolerance, opposition to the introduction of new kinds of tools or what not—these are cases in point. They are all unscientific, and tend to the slavish use of patterns that are out-worn or antiquated, that were developed to meet situations no longer present—simply because it is easier to move in a rut than to put forth the effort to improve the road.

**Prejudice and Open-Mindedness as Social Attitudes.** The above contrast of mental attitudes (scientific and unscientific) is most meaningful when applied to such complex and interwoven group relations as exist in modern civilization. Broadly organized

or socialized prejudice has the same effect on a national or international community as it does on the mind of the individual. Prejudice is characteristic of all types of culture whether it is woven into a class group pattern in a static order (such as caste) or into a pattern of organized opposition (as in feud warfare). Either form is unfavorable to growth; either tends to prevent the use of intelligence; either may lead to group extermination. But a prejudice which becomes a permanent part of a harmonized scheme operates quite differently from a prejudice which is not institutionally and socially harmonized. The first makes for stasis, an unchanging social order; the second makes for irritation, unrest, resentment, violence. There are many examples of each of these two kinds of results. Cultural or social stasis, like instinct and habit, has its advantages and its disadvantages. The caste system (characteristic of old-time Indian and other Oriental social systems) is a system of rationalized beliefs that makes for cooperation between social parasites and their hosts. A caste system operates to allay irritation, prevent resentment and conflict. The results of social stasis as exemplified in modern civilization are: (1) a congested population (because destructive conflict is abated); and (2) social degeneration. Unrest, resentment, class organization, conflict between exploiting and exploited classes, are characteristic of Western peoples. Out of the conflicts so frequent in Western civilization, traits have been developed which, combined in cultural systems, have given to the world many patterns of destructive warfare. Latterly, fighting has resulted in resort to deliberation and a better understanding of human nature. Commonly accepted principles of human nature were formulated by Grotius about three centuries ago, in "The Law of Nature." It was this larger vision gained through struggle which gave to the Occident a civilization quite different from that characterized as Oriental. Refusal on the part of exploited classes to accept with complacency a group cultural pattern, with distinctive traits that made for their subservience, led first to fighting, finally to parley. The demand was for individual freedom from prejudice—religious freedom, intellectual freedom, science. Deliberation based on evidence developed a collectivism whose conscious objective was the welfare of peoples as distinguished from domination by privileged classes. The virtue of both science and democracy

is their breadth of appeal. The elasticity of a fighting Western civilization has been favorable not only to democracy (counting heads instead of smashing them); it has also been favorable to the growth of science, the encouragement of invention, the progress of civilization. But what is quite as significant, the conscious social objective (common welfare) has directed the pressures of liberty-loving, militant peoples to the establishment of justice based on ideals of equality before the law. This attitude of mind has had the effect of insistence on the maintenance of institutions for the adjustment of conflicts by scientific inquiry—by the taking of evidence, the process of deliberative and reflective reasoning. It was in the courts that the scientific method first became socialized. The demand of Western civilization for rational adjustment was later applied to the solution of all problems by the aid of science and by a procedure of group deliberation based on evidence. Such is the ideal which finds expression in our American constitutions—the political aspect or trait of the Occidental cultural pattern.

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PART TWO  
INANIMATE NATURE



## CHAPTER IV

### THE MATERIAL UNIVERSE\*

#### The Philosophical Background of Science

**Philosophy as a Forerunner of Science.** Science, as a mental attitude and as a method, was neither discovered nor invented. It grew. In Greek philosophy we find the first faint flicker of

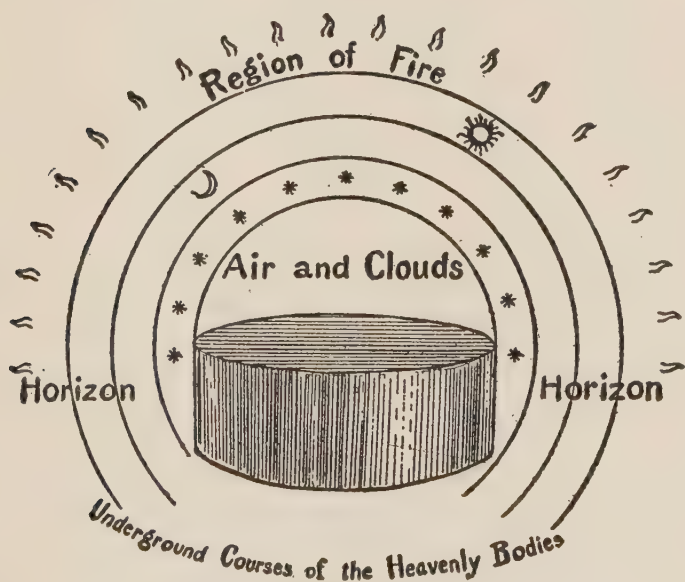


Figure 6. The Universe according to Anaximander

the torch of science. But soon the flame went out, and for two thousand years there were only a few smouldering embers. Thales of Miletus seems to have been the first person to have the "idle curiosity" for knowledge of things. He wanted a theory about

\* By Carl Ellsworth Smith, Head of the Science Department, Malden (Massachusetts) High School; B.S., 1920 (Bates).

the real character of nature. At first, philosophy was confined to a physical basis. Soon after Thales, four explanations of the universe were offered. According to one of these, all things were thought of as composed of water. According to the others, all things were conceived of, respectively, as composed of air, fire, or atoms. Along with these attempts at an explanation, astronomical

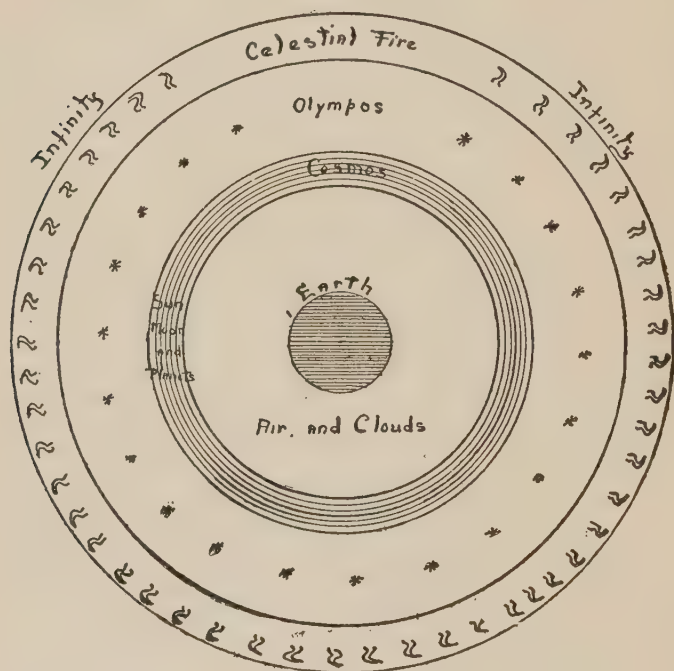


Figure 7. The Universe according to Pythagoras

observations and speculations were carried on for the purpose of placing the earth and heavenly bodies in a scheme of nature. Considerations of time, space, motion, and weight were the bases, many centuries later, for the development of physics and mathematics.

Greek philosophy reached its height with Aristotle, "The Philosopher." He produced hundreds of volumes running the gamut of man's knowledge. He wrote on Logic, Physics, Astronomy, Meteorology, Poetics, Zoölogy, Economics, Ethics, Politics,

and Metaphysics. For the first time, there was an attempt made at scientific nomenclature and orderly classification. But scientific growth was doomed. The method of verification was lacking. Philosophy remained purely speculative, with no experimentation or checking up on data. As Robinson says, "After two or three hundred years of talking in the market place and of philosophic discussions prolonged until morning . . ."<sup>1</sup> philosophy sank in the "muddy stream of metaphysics,"<sup>2</sup> and carried science with it. The rescue came 1,500 years later.

**A Priori Basis of Science.** Besides the historical relation of philosophy and science, there is a more intimate connection which forms the starting point for all scientific thought. It is not necessary to attempt to account for the origin or nature of these principles; that is the work of the several schools of philosophy. The scientist, of necessity, acknowledges and accepts these principles without trying to explain them. We will consider only a few of the most important.

At the very outset, a scientist must recognize the existence of himself. Without knowledge of a self, there would be no foundation for science. Generalizations would be impossible. The existence of other beings, with whom general notions about the nature of the universe can be exchanged, is also recognized. From general notions come ideas, which are resolved into judgments, and judgments are put into proper relations to form conclusions.

But before man goes through these stages of reflective thinking, he must make a second assumption which lies in the field of logic; this is, that there are laws of thinking. *The law of identity* affirms that whatever is, is. A rose is a rose. *The law of contradiction* states that a thing cannot both be and not be. A rose cannot both be a flower and not be a flower. *The law of the excluded middle* means that a thing either must be or not be. A rose must be a flower or not be a flower. *The law of sufficient reason* is that relations between things must never be assumed without sufficient reason. When a beginning is made to form general notions into scientific conclusions, the validity of these laws of thought is accepted.

<sup>1</sup> J. H. Robinson, *The Mind in the Making*, p. 111. Harper, 1921.

<sup>2</sup> W. Durant, *The Story of Philosophy*, p. 2. Simon & Schuster, 1926.

The third necessary basis for science is that nature is capable of being understood, and that the universe is governed by natural laws. If man did not assume that by the application of the laws of thought, he could comprehend the structure and activities of nature, the idea of developing a science would never have occurred to him. In his attempt to gain a more complete knowledge of the orderliness of nature, the scientist comes in contact only with attributes and properties. But these terms are meaningless unless the existence of some substance that has attributes and properties be assumed. If substances exist, they must exist in time and space. Everything must exist or occur somewhere or sometime. We cannot conceive motion without assuming space traversed and time occupied. The idea of substance in time and space gives us the last factor in assuming the orderliness of nature—that a certain sequence of phenomena will always follow the same initial causes.

**Subject Matter of Metaphysics.** Metaphysics is inquiry into ultimate and fundamental reality. It leads to two final questions. The first problem, *ontology*, is stated by the question: "In what does the ultimate reality of nature consist?" The other major problem, *cosmology* or *theology*, tries to answer the question: "What is the connection between all things?" The answer to the first question is found in the explanation of the universal notions and attributes common to all things—entity, non-entity, essence, existence, unity, identity, diversity, and continuity. There are three answers to the ontological problem: (1) that all reality is ultimately *material*, as held by the *materialistic* school; (2) that the nature of things is fundamentally *mental*, as believed by the *idealistic* school; (3) that there is a *dual existence*, both material and mental, on which the tenets of *dualism* are based. These problems carry the thinker into a wide range of speculation—mirages, as Durant calls them—with little regard for verifying the hypotheses. The second problem deals more intimately with the relation of man and the universe to God. The premises upon which a system of metaphysics is built are accepted as absolute. Experimental verification is impossible by the very nature of the subject matter. It is this attitude of mind and lack of verification that separates metaphysics from science.

In science a premise is merely a working hypothesis. It must be either proved by verified experiment or observation, or held in abeyance until more data, bearing on the validity of the hypothesis, have been collected.

**The Medieval Metaphysical Mind.** The popular opinions of the medieval mind were purely metaphysical. Man's position

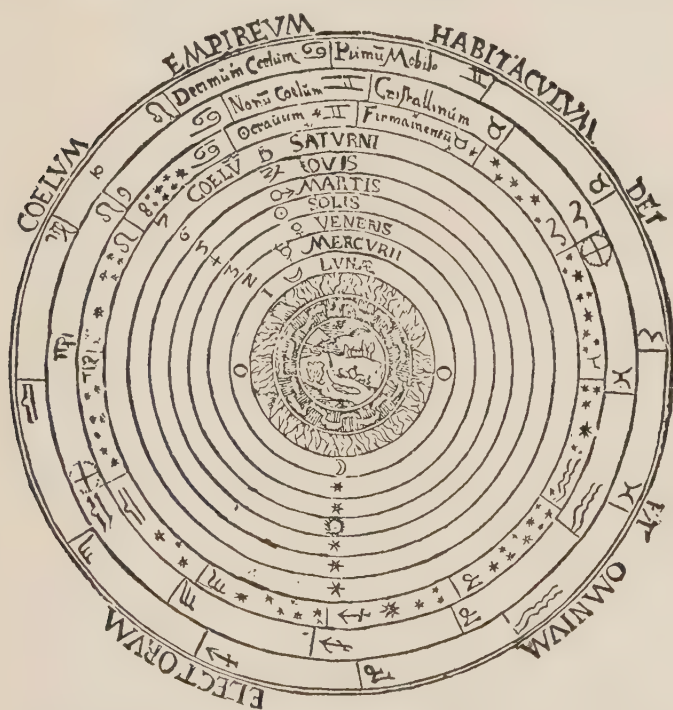


Figure 8. The Celestial Spheres. (From Apian's *Cosmographia*.)

in the universe was authoritatively defined, about the middle of the 12th century, by Peter Lombard, whose *Sentences* "remained until the end of the Middle Ages, the universal manual of theology."<sup>3</sup> "Just as man is made for the sake of God—that is, that he may serve Him—so the universe is made for the sake of man—that is, that it may serve *him*; therefore is man placed at

<sup>3</sup> A. D. White, *A History of the Warfare of Science with Theology in Christendom*, Vol. I, p. 117. Appleton, 1925.

the middle point of the universe, that he may both serve and be served.”<sup>4</sup> From the earth, located then by ecclesiastical authority at the center of the universe, man looked into the sky and pictured the celestial bodies as fastened to the surfaces of transparent, concentric spheres. Each successive sphere inclosed all of the smaller ones. The moon was on the nearest, the sun on the fourth, and the stars on the eighth. The ninth sphere was the *primum mobile*. Inclosing all, and separating the universe from the outer void, was the tenth sphere, and here, in heaven, sat God listening to the “music of the spheres” as they rotated. Kepler even wrote down the tunes that the spheres played. “The Earth sings the notes MI, FA, MI, so that you may guess from them that in this abode of ours MISery (misericordia) and FAMine

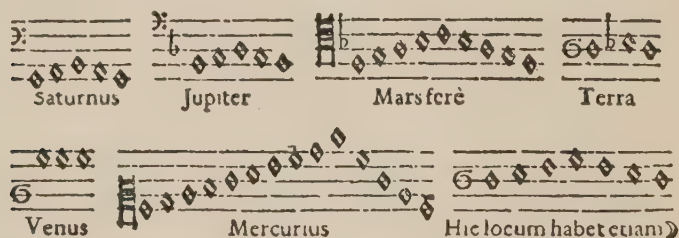


Figure 9. The “Music of the Spheres,” according to Kepler. (From *The Harmony of the World*.)

(fames) prevail.”<sup>5</sup> In this universe were vast hosts of angels, divided into three groups. One group remained in heaven, chanting continually and singing divine praises. Another group was placed between heaven and earth to receive God’s commands and to rotate the spheres. The last hierarchy served the earth. Some of these angels guarded nations and kingdoms; others guarded religion. Each person had a special angel assigned to him as a constant attendant and protector; still other angels had charge of the quality of things, as stones, animals, plants.

Beneath the earth was hell, inhabited by the Devil, many lesser devils, the fallen angels, who had revolted under Lucifer, and, finally, the lost souls. Hell was full of fire and brimstone, which sometimes burst forth from volcanoes. Some of the fallen

<sup>4</sup> *Ibid.*, quoting Peter Lombard.

<sup>5</sup> A. Berry, *A Short History of Astronomy*, p. 191. John Murray, 1898.

angels roamed among the spheres, trying to undo the work of the good angels. Others lived in our atmosphere, causing lightning, storms and tempests, hail and drought. But most numerous were those demons who lived on the earth, causing all kinds of illness and insanity by diabolical possession, hideous nightmares, epidemics, and constantly tempting man to sin. Man was thus on the boundary between the power of God and the Devil, buffeted between those who tried to bring him happiness and those who tried to lure him to his destruction. Sometimes demons took human form. These were the witches who caused whirlwinds, frosts, floods, soured milk, carried off children on broomsticks, and cast spells on persons by means of an "evil eye." Alchemists dealt in the black art, turning people into animals, particularly into wolves or swine, and even into lifeless matter. Stars and meteors foretold the birth of gods, great men, or heroes. To the medieval mind, "Whatever moves in the heaven in an unusual way is certainly a sign of God's wrath."<sup>6</sup> No longer was Vulcan forging thunderbolts for Jupiter to hurl; people now recognized in thunder the voice of an angry God. From pagan mythology came the belief that an eclipse was the way that nature mourned over some great earthly calamity. Even in the Colonial period of our country, Increase Mather wrote that an eclipse of the sun was the expression of nature's grief at the death of President Chauncey of Harvard College.<sup>7</sup> Comets were balls of fire, "harlot stars," flung by an angry God to warn the sinners. They foretold revolution, war, pestilence, famine, wind, snow, heat, and every kind of calamity. Man was surrounded by mysteries and beset with fear; good and evil spirits were everywhere. At all times was he the sport of an arbitrary God and a malicious Devil. Miracles became everyday occurrences. Men looked upon the products of their own metaphysical minds and saw what they thought were realities in nature. Why search for new vistas of truth, when Truth itself had been found, once for all, by supernatural revelations and the metaphysics of scholasticism, and had then been formulated into elaborate theological dogma? It was but natural that in this metaphysical world man's greatest thought was to escape hell and to get to heaven. To be saved one had only to believe.

<sup>6</sup> A. D. White, *op. cit.*, Vol. I, p. 182, quoting Luther. <sup>7</sup> *Ibid.*, p. 173, note, p. 174.

**The Dawn of Science.** "Scientific principles and laws do not lie on the surface of nature. They are hidden, and must be wrested from nature by an active and elaborate technique of inquiry. Neither logical reasoning nor the passive accumulation of any number of observations—which the ancients called experience—suffices to lay hold of them. Active experimentation must force the apparent facts of nature into forms different to



Figure 10. The Universe according to Ptolemy

those in which they familiarly present themselves, and thus make them tell the truth about themselves, as torture may compel an unwilling witness to reveal what he has been concealing. Pure reasoning as a means of arriving at truth is like the spider who spins a web out of himself. The web is orderly and elaborate, but it is only a trap."<sup>8</sup> This trap of metaphysics completely enmeshed men's minds until the middle of the 16th century—with

<sup>8</sup> J. Dewey, *Reconstruction in Philosophy*, p. 32. Holt, 1920.

one outstanding exception. Roger Bacon, who lived in the first part of the 13th century, was the only man, during an expanse of 1500 years, who advocated and practiced the scientific method of verified observation and experimentation. But men were not yet ready to follow this true prophet who, 700 years ago, told of the coming of steamboats, automobiles, modern suspension bridges, and airplanes. During the next centuries, the discovery of the compass and the subsequent voyages of Columbus, Vasco da Gama and Magellan stimulated travel, exploration, and commerce, which are always broadening influences on the minds of men. The trader became more important and saw the need of new methods of manufacture. The Reformation emphasized individual conscience rather than some external authority.

Francis Bacon, in the 16th century, "rang the bell that called the wits together." Copernicus, Galileo, Kepler, and Newton turned their scientific methods and instruments on the heavens, and found an orderly universe, of which the earth was but a tiny and insignificant part, governed by immutable natural law. Algebra was developed and logarithms invented, thereby giving impetus to the physical sciences. The founders of anatomy, dissection, surgery, and physiology led the way to a more complete understanding of the cause, treatment, and cure of illness. Scientific observations were started in zoölogy, biology, geology, and mineralogy. The microscope opened up as wonderful a world as had the telescope. Everywhere that the scientific method and attitude penetrated, natural law was found to be operative. Miracles gave way to medicine; magic turned into chemistry. The recognition that nature was controlled by unchangeable natural laws, instead of an arbitrary, interfering, man-made God and hosts of demons and devils, was the dawn of science. The thoughts of men turned from speculations on heaven and hell to problems of making this world a better place in which to live.

**Science the Approach of Practical Man.** The scientist turns his attention to common concrete things. Nothing is unworthy of his most searching investigation; his quest for laws is among things—changing things; his absolutes are found not in revelation or external authority, but in the laws of nature. The mate-

rial world is his field of work; verified observations are his data, to be classified and arranged into rational systems of thought. "The scientist is a practical man, and his are practical aims. He does not seek the *ultimate*, but the *proximate*. He does not speak of the last analysis but rather of the next approximation. His are not those beautiful structures so delicately designed that a single flaw may cause the collapse of the whole. The scientist builds slowly and with a gross but solid kind of masonry. If dissatisfied with any of his work, even if it be near the very foundations, he can replace that part without damage to the remainder. . . . The theory that there is an ultimate truth, although very generally held by mankind, does not seem useful to science except in the sense of a horizon toward which we may proceed, rather than a point which may be reached."<sup>9</sup>

**Mental Pictures Developed in Organizing Experience.** The only way that man can become aware of his environment is through external stimuli. The sensations produced are organized by reason as ideas. But reason is as likely to organize these sensations in a wrong manner as in a right. Ideas which cannot be verified by test or by critical reflection (i. e., by association with sensations subsequently aroused, or with ideas previously verified) have no counterpart in nature. They are false mental pictures of one's environment. These unverified ideas may be of use in acting as subjective stimuli for further reasoning; but, when they are organized into systems, they give an interpretation of nature which is, of necessity, untrue. If, on the other hand, these ideas or hypotheses are verified or modified, they then, and only then, become dependable guides to judgment. The mental pictures made by scientists are the stepping stones by which each new generation climbs to its "endless and persistent uncovering of facts and principles not (yet) known," in its invasion of the parts of nature still unexplored. These scientific beliefs, organized as plastic structures, grow to meet the needs of the ever-widening horizon of intelligence, as it reaches out in response to the divine urge to know and master the material universe.

<sup>9</sup> A. N. Lewis, *The Anatomy of Science*, pp. 6, 7. Yale Univ. Press, 1926.

## Matter—Energy—Mechanism

**Basic Factors Common to All Natural Sciences.** All natural sciences deal with two fundamental entities. The first is *matter*.<sup>10</sup> Anything that occupies space is matter. It forms all the things in nature. We ordinarily picture matter in one of three states—solid, liquid, or gaseous; but more recently a fourth has been added, called colloidal.<sup>11</sup> The second basic factor is *energy*. It is the capacity to do work, or, as commonly conceived, the ability to make matter move through space. Energy exists in two fundamental forms: (1) potential, or energy of position in space, and (2) kinetic, or energy of motion. Each of these forms may be transformed into the other. Thus, that immortal apple which fell on Sir Isaac Newton's head had potential energy when hanging on the tree, and kinetic energy when it hit Newton. Energy is, of necessity, associated with matter or mechanism, by or on which the energy is exerted. One cannot conceive energy except as related to some kind of structure or mechanism.

**Need for Accurate Definition.** If we are to have true mental pictures of the structure and activity of matter and of the manifestations of energy, we must "wrest (them) from nature by an active and elaborate technique of inquiry." This is the process of scientific verification. Every observation must be analyzed into common elements which can be compared and contrasted by other observers. The most common of the elements used in critical comparison and differentiation are time, space, and mass. Dependent upon these fundamental concepts are others, such a motion, force, pressure, work, power, velocity, acceleration, inertia, momentum, and weight. Accurate comparison requires that units be established, and if the units are to be freely used by scientists in the processes of verification, they must be specifically defined and universally understood. "By the rules of language, a word means what any large body of people suppose it to mean. . . . But science demands some refinement of common ideas, and often more limited and more technical use of

<sup>10</sup> Recent investigations indicate that matter is a manifestation of energy.

<sup>11</sup> See Chapters XIII and XIV.

language.”<sup>12</sup> By this standardization and definition of units, the basis for scientific observation and record is laid. The mental pictures which we may now communicate will have no ambiguous meaning.

**Definition of Terms.** By *time* we mean an idea organized from a succession of sense impressions by reference to intermediate events. *Space* is an idea organized from sense impressions by reference to intermediate positions. The unit for time measurement is the second, or some multiple of it. A second is  $1/86,400$  of the mean solar day, the mean solar day being the average time throughout the year which elapses from noon to noon. The unit for space measurement is the *meter*, or some decimal fraction thereof. A meter is defined as the distance, at the temperature of melting ice, between the centers of two transverse lines on a bar of platinum which is kept in the archives of the French Government. We sometimes use the *yard* as a unit. The yard is both legally and scientifically defined as  $3,600/3,937$  of a meter. *Mass* means the quantity of matter in a body. The unit of mass is the *gram*, which is  $1/1,000$  of the mass of a certain piece of platinum-iridium, known as the standard kilogram, and also kept in the French archives. A pound is approximately 454 grams. Now with these three basic elements in mind, we can define the secondary concepts in the same terms. *Motion* means change of position in space. *Force* is that which changes, or tends to change, the motion of a body. It is thought of as a push or a pull, in grams or pounds. *Pressure* is the force exerted on a unit area, as “pounds per square inch,” or “grams per square centimeter.” *Work* is the product of a force and the distance through which the force moves. Thus one pound of force moving through one foot of space equals one foot-pound of work. *Power* is the rate of doing work; 550 foot-pounds of work per second is one horsepower. *Velocity* means the distance a body passes over divided by the time occupied by the body in passing, as an automobile’s velocity being 40 miles per hour. *Acceleration* is the rate at which velocity is gained or lost. *Inertia* is the tendency of matter to maintain its condition of motion or of rest, i.e., to remain in its status quo. *Momentum*

<sup>12</sup> Lewis, *op. cit.*, p. 29.

is the quantity of motion that a body has. *Weight* is the mutual attraction between the mass of the earth and the mass of another body. It is a force acting on a body, rather than a description of what that body contains.

Such are the concepts which are used by all natural scientists. Without such an understanding of the terms used to describe natural phenomena, there could be no careful observation, accurate verification, classification, or correlation. No critical thinking could be done.

**The Conception of Matter as Mechanism.** We have seen that matter and its manifestations form the field of inquiry for natural science. It is obvious that one is unable to think of motion without thinking of some matter as performing that motion. There can be no weight without matter to have that weight. Now all matter, whether the smallest atom or the grandest galaxy of stars, is arranged in a system, or *mechanism*. "Mechanism is probably universal."<sup>13</sup> This knowledge of the orderliness of nature is the grandest discovery of science. Mechanism is considered as either made by man or evolved by nature. The mechanisms which are man-made are called machines or, if the parts are persons, they are termed associations, such as corporations, political machines, secret orders, families. The mechanisms evolved by nature are divided into two broad classes, the non-living and the living.

In the non-living group we find systems called atomic, molecular, planetary, solar, stellar, cosmic, etc. The *atom*, we believe, is the unit mechanism of matter. The system may be simple, consisting of only 2 parts, as in the hydrogen atom, or most complex, as in the uranium atom with 576 parts. These mechanisms are so small that the diameter of the atom, in the case of helium, must be magnified three hundred million times to equal an inch. In between these two extremes of atomic mechanisms there are 90 others, varying in their degrees of complexity, each one forming a complete mechanism by itself.

Atoms generally arrange themselves in larger mechanisms, called molecules.<sup>14</sup> If the atoms are all of the same kind, we call that mechanism an *element*, if of different kinds, a *com-*

<sup>13</sup> Durant, *op. cit.*, p. 538.

<sup>14</sup> The molecules of some elements, as helium, consist of but a single atom.

found. This mechanism may be a relatively simple arrangement, as of hydrogen and oxygen in water,  $H-O-H$ , or a highly complex system of several kinds of atoms, as shown in the diagram.

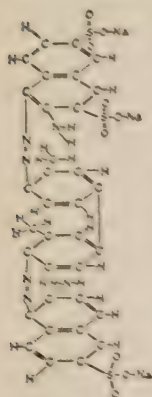


Figure 11.  
A Molecule of  
Brilliant Congo  
Dye

When you buy a package of Brilliant Congo Dye, you really get a package of these complicated mechanisms. Molecules sometimes arrange themselves into more completely organized mechanisms, called crystals. Each kind of crystal has a definite arrangement of the simpler mechanisms, atoms or molecules. The impressive fact is that we always find an orderly, systematically arranged mechanism.

The earth, a group of geologic systems in itself, is a member of a larger mechanism, the solar system. Here again we have a definite arrangement of smaller mechanisms called planets, moons, planetoids, etc. Our solar mechanism is so large that we cannot imagine its true size. If the diameter of the earth is represented by *one inch*, the diameter of our solar system would be *seven miles*.

But mechanisms do not stop here. Our solar system is but a tiny speck in our stellar system, a mechanism some hundred million times larger than our solar system. Yet this stellar system, of which we are but a puny part, does not reach out to an infinite distance and monopolize the universe, as we once thought. Terrifying as it may seem, there are "enormous numbers" of complete stellar systems entirely outside of ours. It seems reasonable to assume that "many galaxies, perhaps millions, are the constituent parts of a super-galaxy. Then the question arises whether or not there are other super-galaxies, and the affirmative answer seems more probable than the opposite. The mind shrinks from the conclusion that there is not order here, and consequently it postulates, tentatively, that many super-galaxies of the first order constitute a super-galaxy of the second order, and so on, in an unending sequence."<sup>15</sup>

Thus we see that in the non-living world, from the tiniest atom to the vast super-galaxy, there is nothing haphazard or accidental, but only perfect order of mechanism.

<sup>15</sup> H. H. Newman, ed., *The Nature of the World and of Man*, p. 28. Univ. of Chicago Press, 1926.

This concept of matter as mechanism holds equally true in the animate world, whether we consider a microscopic bacterium, a giant sequoia, an amoeba, or a whale. For any living body is composed of the same atomic and molecular mechanisms that comprise non-living forms. These smaller mechanisms are arranged in systems called *cells*.<sup>16</sup> We find nothing capricious in the mechanism of these units of living matter. One certain arrangement produces a mechanism recognized as a bone cell; another arrangement will produce a nerve cell; still another a muscular cell, etc. Cells performing like functions group themselves to form a larger mechanism, a *tissue*. Tissues unite to form organs, which, in turn, form mechanisms commonly known as the circulatory, digestive, respiratory, excretory, nervous, skeletal, muscular, and reproductive systems. And finally these several mechanisms are coordinated to form the most completely organized mechanism we find in nature—the living body. The living body is a mechanism. It may be something more, a mechanism plus; but mechanism it is.

Mechanism is not confined to inanimate and animate nature, but extends throughout the realm of human nature. The mechanisms here operate under psychical, not physical laws. Persons are the units of psychical organization. Like-minded persons form associations such as religious groups, philanthropic orders, business and trade organizations. These associations are the organs of a larger human mechanism—the community. A community is a social population made up of individuals united by psychical bonds. This is a case of making organisms (individual machines) cooperative by developing common states of mind—thinking, feeling, and willing together. Many communities unite to form a super-community. Super-communities of the first order form a super-community of the second order, the sequence again continuing until, theoretically at least, it is conceivable that there may be a federation of the world. Hence, we see that the natural scientist deals with mechanism manifest in either living or non-living forms. Care should be taken not to confuse mechanism as a structure with materialism as an interpretation of mechanism. Such confusion of terms will lead

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<sup>16</sup> See Part III.

back to the "muddy streams of metaphysics," which lie entirely outside the field of natural science.

**Science, Descriptive and Normative.** When dealing with the natural universe, science presents two aspects. One attempts to describe mechanism and explain the phenomena observed. The other undertakes to develop a method of abstraction, induction, deduction—of analyzing wholes into parts, and of synthesizing parts into wholes—and also to direct imagination and judgment when dealing with these problems. Those sciences that deal with concrete observations of mechanisms found in nature are called the descriptive and explicative sciences—examples of which are found in the chapters that immediately follow. The normative sciences—such as ethics, logic, mathematics—are composed of "systems of propositions whose contents are not facts, but norms; not experiences, but values, and whose teaching is, therefore, not that something is, but that something ought to be."<sup>17</sup>

**The Field of the Descriptive Sciences.** It is impossible to definitely divide the fields of the several descriptive sciences by definition. Many times the sciences overlap, as in astrophysics, biochemistry, and physical chemistry. These definitions will, therefore, give but a general field of the sciences which follow.

*Astronomy* deals with the attributes of solar and sidereal mechanisms.

*Geology* studies the structure of the earth and its history as revealed by the natural mechanisms of land and water.

*Physics* is the science of the nature of (1) atomic mechanism, (2) man-made mechanism, known as machines, and (3) the transformation of energy from one mechanism to another.

*Chemistry* treats of (1) the processes whereby an atomic or molecular mechanism, known as a substance, is transformed into a different mechanism, or substance, and (2) the nature of this transformation.

*Biology* has as its field the study of mechanisms which are now, or have been alive.

*General psychology* deals with the mind as a control mechanism governing individual behavior.

*Social psychology* studies the manifestations of a larger

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<sup>17</sup> *Ency. Americana*, article "Sciences, normative."

mechanism, "the group mind," as it regulates and controls group behavior.

*Sociology* has for its subject a community or super-community mechanism as composed of persons, associations, and institutions.

The chapters that immediately follow in Part Two discuss the various forms and activities of mechanisms that the scientist studies in the specialized fields of astronomy, geology, physics, chemistry, and colloid science.

### QUESTIONNAIRE WITH READING REFERENCES

(The breadth of this brief introductory statement and the fact that the natural sciences are each discussed in the chapters which follow have suggested the desirability of leaving questions largely without specific references to readings.)

#### 1. What were the contributions of Greek philosophy to science?

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W. T. Sedgwick and H. W. Tyler, *A Short History of Science* [N. Y.: Macmillan, 1917], Ch. III, The beginnings of science, pp. 35-57; Ch. IV, Science in the Golden Age of Greece, pp. 58-86; Ch. V, Greek science in Alexandria, pp. 87-114.

A. Berry, *A Short History of Astronomy* [London: John Murray, 1898], pp. 21-33.

J. H. Robinson, *The Mind in the Making* [N. Y.: Harper, 1921], pp. 97-111.

A. N. Whitehead, *Science and the Modern World* [N. Y.: Macmillan, 1925], Ch. I, Origins of modern science, pp. 1-27.

#### 2. What were the reasons for the decline of Greek science?

Robinson, *Mind in the Making*, pp. 112-113.

Draper, *op. cit.*, pp. 205-206.

#### 3. What is fundamental to scientific observation?

A. Comte, *Positive Philosophy* [N. Y.: Blanchard, 1858, Martineau, trans.], Bk. VI, Ch. XV, Estimate of the final action of the positive philosophy, pp. 828-838.

L. T. Hobhouse, *Mind in Evolution* [London: Macmillan, 1915], pp. 366-368.

Robinson, *The Mind in the Making*, pp. 33-62.

F. S. Hoffman, *The Sphere of Science* [N. Y.: Putnam's, 1898], pp. 36-38.

#### 4. What is meant by the *a priori* basis of science?

#### 5. What are the necessary assumptions for the beginning of a science?

#### 6. What are the laws of thought?

Hoffman, *op. cit.*, pp. 24-28.

W. S. Jevons and D. J. Hill, *Elements of Logic* [N. Y.: American Book Co., 1911], pp. 104-108.

#### 7. Why must a philosophy of life precede scientific observation?

G. T. Ladd, *Introduction to Philosophy* [N. Y.: Scribner's, 1898], Ch. III, Relation of philosophy to the particular sciences, pp. 55-83.

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J. M. Baldwin, *Fragments in Philosophy and Science* [N. Y.: Scribner's, 1902], Ch. I, Philosophy: its relation to life and education, pp. 3-23.

Hoffman, *op. cit.*, pp. 32-39.

#### 8. What are the two general aspects of metaphysics?

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*Ency. Britannica*, Vol. XX, article "Ontology."

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Comte, *op. cit.*, Introduction, Ch. I, View of the nature and importance of the positive philosophy, pp. 25-37.

K. Pearson, *The Grammar of Science* [London: Black, 1911, 3d ed. rev.], pp. 14-23.

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11. What were the causes of the dawn of science?

Draper, *op. cit.*, Vol. II, pp. 150-175; Ch. VI, The age of reason, pp. 190-228; Ch. VIII, The European age of reason, pp. 252-293.

J. Dewey, *Reconstruction in Philosophy* [N. Y.: Holt, 1920], Ch. II, Some historical factors in philosophical reconstruction, pp. 28-52.

12. What contributions did Roger Bacon make?

Draper, *op. cit.*, Vol. II, pp. 153-155.

J. H. Robinson, *Readings in European History* [Boston: Ginn, 1904, 2 vols.], Vol. I, pp. 460-461.

A. D. White, *A History of the Warfare of Science with Theology in Christendom*, [N. Y.: Appleton, 1925, 2 vols.], Vol. I, pp. 379-391.

Sedgwick and Tyler, *op. cit.*, pp. 177-180, 400-407.

13. What were the major contributions of Copernicus, Galileo, Newton, Kepler?

Sedgwick and Tyler, *op. cit.*, Ch. X, New astronomy and the beginnings of modern natural science, pp. 191-229.

Berry, *op. cit.*, Ch. VIII, From Galileo to Newton, pp. 198-209; Ch. IX, Universal gravitation, pp. 210-246; Ch. X, Observational astronomy in the 18th century, pp. 247-286.

14. What were some of the scientific discoveries of the 16th and 17th centuries?

Sedgwick and Tyler, see reference to question above.

Draper, *op. cit.*, Vol. II, pp. 284-287.

15. Why must all scientists be practical men, and the categories of analysis, descriptive and interpretive, be such as are of practical use?

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16. How is a system or the mechanistic conception related to energy, i.e., thinking of energy as capacity to do work, is this conceivable except as related to mechanism or a system?

Lewis, *op. cit.*, Ch. VII, Non-mathematical sciences, pp. 163-190.

*Ency. Britannica*, Vol. IX, article "Energy."

17. Thinking of the common factors with which all the physical sciences deal, in what uniting conception are the two ideas, matter and energy, joined?

Pearson, *op. cit.*, Ch. VII, The geometry of motion, pp. 220-265.

J. Mills, *The Realities of Modern Science* [N. Y.: Macmillan, 1919], Ch. IX, Energy, pp. 101-114.

*Ency. Britannica*, Vol. IX, article "Energetics."

18. How is the mechanistic conception related to the idea matter?

Lewis, *op. cit.*, Ch. IV, Matter in motion, pp. 87-112.

*Ency. Britannica*, Vol. XVII, article "Matter."

*Ency. Rel. and Ethics*, Vol. VIII, article "Matter."

19. What are the three principal categories or attributes of matter: i.e., thinking of matter as entity, what are the three attributes in terms of which all of the other categories of scientific classification, analysis and interpretation are definable?
20. How are mass, space and time defined by scientists?  
 W. James, *Psychology: Briefer Course* [N. Y.: Holt, 1892], Ch. XVII, The sense of time, pp. 280-286; Ch. XXI, The perception of space, pp. 335-350.  
 Lewis, *op. cit.*, Ch. II, Space and geometry, pp. 29-58; Ch. III, Time and motion, pp. 59-86.  
 Pearson, *op. cit.*, Ch. VI, Space and time, pp. 179-219.  
*Ency. Britannica*, Vol. XXV, article "Space and Time."  
*Ency. Rel. and Ethics*, Vol. XI, article "Space"; Vol. XII, article "Time."
21. What are the minor categories or attributes commonly used in scientific observation, description, and interpretation?
22. Define body or particle, energy, mechanism, movement, pressure, force, power, work, weight, momentum, in terms of mass, space, and time.
23. What is the static conception of matter; how does this differ from the dynamic conception; what is meant by potential energy; what is meant by kinetic energy?
24. When thinking about nature statically, what is meant by the phrases "constitution of matter," "states of matter"?
25. What are the main categories used when thinking about the "constitution of matter"; in general terms, what is meant by elements, compounds, mixtures, molecules, atoms?
26. What are the three "states" of matter as the term is commonly used by natural scientists?
27. What are the "states" of matter as the phrase is used by the colloid scientist?
28. In non-technical language, what is meant by: (a) a gas; (b) a liquid; (c) a solid in amorphous state; (d) a solid in crystallized state; (e) a colloid?
29. What determines whether matter or mechanism is dynamic?
30. What is meant by a dynamic system?
31. What is the dynamic conception of: (a) cosmic system; (b) our solar or planetary system; (c) an industrial plant; (d) a plant organism; (e) the human body as a system?
32. What are the general descriptive sciences dealing with inanimate nature? Define each of these in relation to dynamic "systems."

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## CHAPTER V

### THE UNIVERSE AS SEEN BY THE ASTRONOMER \*

#### Man's Struggle to Comprehend the Universe

**The Beginning of Understanding.** Ages must have elapsed after man appeared on the earth, many thousands of years before he had any organized thought about the universe. Paleontologists and anthropologists give us the picture of primitive man living through periods of great upheaval. Old continents were submerged and new ones were born. Over wide areas, conditions of living must have been radically different from what had gone before. Thus we are not at a loss to understand why it was that great mammals and great reptiles perished—the woolly elephant, the brontosaur, the dinosaur, and many other species. But during these geological ages, it is thought, primitive man must have looked on without having excited in him an interest greater than would be shown by infants today or even by intelligent dogs—turning his eyes toward sun, moon, and stars, sensing heat and cold, wind, storm, and earthquake shocks, scarcely wondering at the meaning of all that was going on about him.

**The Beginning of Cosmological Thought.** It seems probable that there were long reaches of time in which mankind had no sense even of mystery, and formulated no philosophy of life. The most primitive cosmological conceptions are assumed to be a product of a relatively high race culture. And crude though they were, the earliest cosmologies have served well in the advancement of knowledge. They must have been as important to their times as are the conclusions of modern science to our own; for all cosmologies and philosophies—all sweeping generalizations—

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must have had an important part in the ordering of the human mind. The early conceptions of the heavens must have helped man to enlarge his vision of the objective world with which he had to deal. Each in turn must have opened to him a new conceptual world; each must have borne fruit in the progressive development of human intelligence.

### Astrology—a Forerunner of Astronomy

**The Anthropocentric Universe.** The most primitive philosophizing bears the distinguishing label “anthropocentric”—meaning that all thinking about nature was centered in man’s idea of man. The thinker conceived of all things, animate and inanimate, as having thoughts and feelings akin to his own, as being disposed to do him good or harm. The prevailing psychological state was one of fear. Everything that moved, everything that aided man or stood in his way, was pictured as having “an animus” and, therefore, as friendly or unfriendly. Out of such a conception of the material world came the cult of the astrologer.

**The Soothsayer.** Among his fellows, the astrologer served as a professional adviser. He belonged to that more general class, the soothsayers, the seers—those who were commonly regarded as beings possessed of the power to act as intermediaries between man and the unseen forces. Each local group or clan came to have its medicine-man, priest, or what-not, who resorted to different occult arts. The astrologers gained their special knowledge from studying the stars. And because of their studies, they were assumed to be able to foretell and interpret events—to read omens of good fortune as well as of dangers to come. We still find some of this kind of lore, preserved by the astrologers, among fear-controlled populations of the East. The gypsy fortune-teller still makes a living by commercializing such a pretense. Astrology may be said to be the unscientific forerunner of astronomy—the product of an unscientific attitude of mind, of “anthropocentric” thought, which was the beginning of philosophy.

## Scientific Conceptions

**Older Ideas of Astronomers.** At a later stage of human intellectual development, the physical universe came to be conceived of as centered, not in man, but in that very restricted area of the earth's surface with which the thinker was acquainted. This was a notion which led to more painstaking inquiry as a

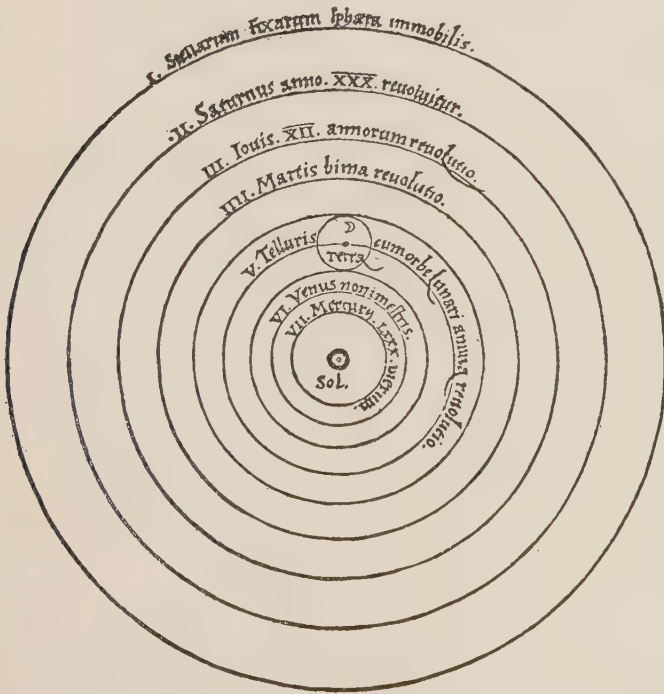


Figure 12. The Solar System according to Copernicus. (From the *De Revolutionibus*.)

basis for reflective reasoning. The seemingly flat, known section of the earth was thought of as arched over with a star-studded vault. A still larger view is associated with the name of Ptolemy; to him and his school, the universe was "geocentric"—i.e., the stellar universe was thought to revolve about the earth. Then came down to us, from the time of Copernicus (1543), the idea that the sun (our sun, the dominating body of the solar

system) was at or near the center of the stellar realm. Each of these theories enlarged man's vision and enabled him to see himself in better perspective.

**The Modern View.** The chief instrument used for expanding knowledge of the stellar universe has been the great observa-



Figure 13. The Universe according to Copernicus

tory. With our powerful reflectors and lenses, new instruments of precision, and methods of analyzing stars and of sounding space, there is ground for belief that we have reached a new epoch—an epoch in which we are taking a very long step in advance of the Copernican concept. Our conception of the surrounding stellar system, the galactic system, must be enlarged to keep in proper perspective the other groups of objects our telescopes are finding. Our solar system can no longer be thought of as having a central position in the cosmic order. The older scientific generalization needs revision, not only as to size, but

also as to organization. Recent studies of star clusters and related subjects seem to leave no alternative to the belief that the galactic system is at least ten times greater in diameter than recently supposed—and at least a thousand times greater in volume. Beyond its limits are the spiral nebulae. What is the relation of the galaxy to them?

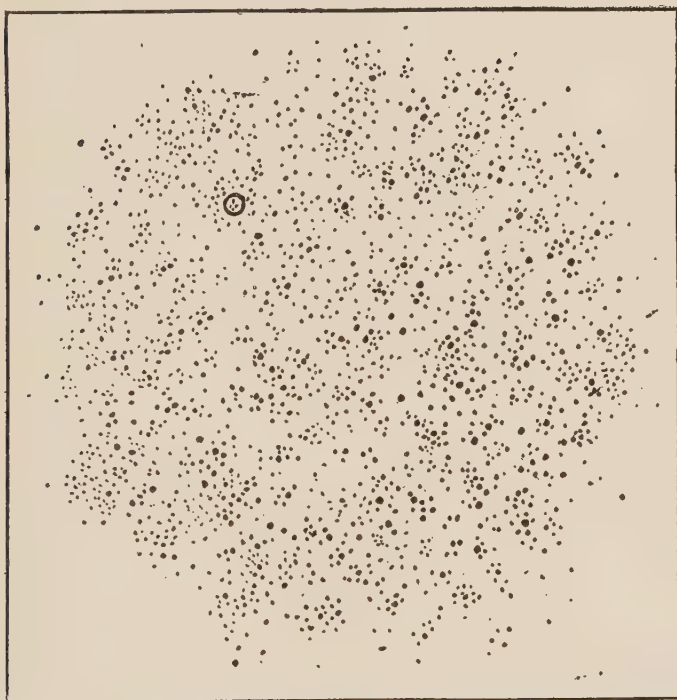


Figure 14. The Shape of Our Universe—as seen from the position in which one looks at the face of a watch. The circle in the upper left-hand portion indicates the position of our solar system, and includes all the stars visible to the naked eye from the earth. (Courtesy of *Harper's Magazine*.)

**The Galactic System.** Let us first recall that the stellar universe, as we know it, appears to be a very oblate spheroid or ellipsoid—a disk-shaped system composed of stars and nebulae. The solar system (our planetary system) appears to be located within this discoidal stellar universe<sup>1</sup> not far from the median

<sup>1</sup> The word "universe" is used in the restricted sense as applying to the total of the known sidereal arrangement.

plane, though not in the center of the flattened organization to which is given the name, the Galactic System. We may imagine ourselves standing in the middle plane; looking away from it, we see relatively few stars; but looking along the plane, through a great depth of star-populated space, we see the vast numbers of sidereal objects that constitute the band of light we call the Milky Way. The loosely organized star clusters, such as the Pleiades; the diffuse nebulae, such as the Nebula of Orion; the planetary nebulae, such as the ring nebula in Lyra; the dark nebulosities—all of these sidereal types appear to be a part of



Figure 15. The Shape of Our Universe—as seen edgewise. The small ellipse at the left of center shows the relative position of the stars which are visible to the naked eye. The crosses indicate the position of globular clusters—outside the central part of the Galaxy—but most numerous near it. The dark patch below is a Magellanic Cloud. (Courtesy of *Harper's Magazine*.)

the great galactic system, and they lie almost exclusively near the plane of the Milky Way. This conception of the galactic system (as a flattened, watch-shaped organization of stars, clusters, and nebulae) is now pretty generally agreed upon by students of the subject.

### Contributions of Astronomy to the Enlargement of Human Knowledge

**Development of the Space Concept.** To the process of reflective reasoning, one of the essentials is an idea of measurable space. For enlarged perspective, mankind is much indebted to

astronomical research. Any notion of distance or volume must relate to some known unit or standard of measurement. On the earth's surface we express distance in units such as inches, feet, or miles, and so we come to have a calculable idea of the distance between definite points or places visited or not visited; by comparison we come to have a notion of the distance through and around the earth. When thinking of the moon we may still use the mile, for the distance to this satellite is only about ten times the earth's circumference. This idea of space is quite comprehensible, because, having traveled around our planet, or thought it out in comparison with known distances, we can imagine how far it would be if we went around ten times. By a stretch of the imagination, miles may also be used when thinking about the distance to the sun, for we can readily think in terms of multiples of thousands. That is within our experience; and we have an idea conveyed when it is said that the sun is about four thousand times as far as the distance around the earth, or four hundred times more distant than the moon.

**Coordinates of Time and Space.** When applied to the measurement of stellar distances, however, the numerical factor stated in miles as a unit would be meaningless. We need a larger unit. Having the picture of the distance in miles to the sun, however inadequate this may be, this idea of distance may be taken as a unit for measuring the longer reaches to planets and comets and various parts of the solar system. This sun-to-earth distance (ninety-three million miles) is called "the astronomical unit." And for many years it has served well enough. It might still suffice to measure distances of whatever planets and comets there may be in the vicinity of other stars. But now with our much enlarged concepts of the galactic system, it is cumbersome for expressing distances from one star to another—for some of these are a hundred million, others a thousand million, and others ten thousand million times the distance from the earth to the sun.

**The Light Second and the Light Minute as Units of Measurement.** We now resort to another device to help us to comprehend the depths of stellar space. In our everyday experience we think of Philadelphia as being two hours from New York; of Chicago as being twenty-four hours from Boston; of San

San Francisco as being "four days" from Washington. We are using the speed of trains in this conception of distance measurement. Washington is four "train days" from San Francisco. After many painstaking experiments, it is found that light travels 186,000 miles per second. Then, by using the speed of light for marking off space we can think of the moon as 1.2 "light seconds" distant, and the sun as eight "light minutes" from the earth.

**The Light Year.** Now when we try to think of the stars, we must elongate our measuring unit to light years. Light travels about six million million miles a year. Six million million (six trillion) means little more to us than an unthinkable dis-

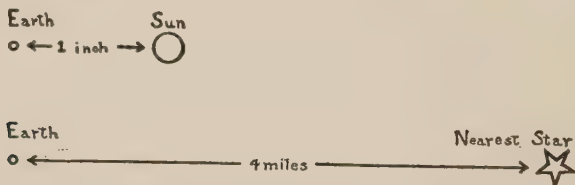


Figure 16. The Old Astronomical Unit. If the distance from the earth to the sun were represented by *one inch*, the distance to the nearest star, on the same scale, would be *four miles*.

tance. But given the distance that a ray of light will travel in a year as our unit of measurement, we get better perspective when we know that it will take four years for the light of the nearest fixed star to reach us. Now having the distance to the nearest star expressed in terms of light years (four light years), we may use the same unit for comparison when attempting to see the more distant members of the great galactic system.

**Measuring the Extremes.** In some phases of our astronomical problems (studying photographs of stellar spectra) we make direct microscopic measurements of a ten-thousandth of an inch; and indirectly we measure changes in the wave length of light a million times smaller than this. In discussing the arrangement of globular clusters in space, we must measure a hundred thousand light years. Expressing these large and small measures with reference to the velocity of light, we have an illustration of the scale of the astronomer's universe; his calibrations range from

the trillionth of a billionth part of one light second, to more than a thousand light centuries.

**Actually Seeing the Happenings of Thousands of Years Ago.** It is to be noticed that light plays an all-important rôle in the study of the universe: We know the physics and chemistry of stars only through their light; their distances from us we express by means of the velocity of light. The light year, moreover, has a double value in sidereal exploration; it is metrical, as we have seen; and it is historical, for it tells us not only how far away an object is, but also how long ago the light we examine was started on its way. You do not see the sun where it is, but where it was eight minutes ago. You do not see faint stars of the Milky Way as they are now, but more probably as they were when the pyramids of Egypt were being built, or at a time still more remote.

**An Enlargement of Historic Perspective.** We are, therefore, chronologically far behind events when we study conditions or dynamic behavior in remote stellar systems. The motions, light emissions, and variations now investigated in the Hercules cluster are not contemporary, but, if my most recent valuation of the distance is correct, they are the phenomena of 33,000 years ago. The great age of these incoming pulsations of radiant energy is, however, no disadvantage; in fact, their antiquity has been turned to good purpose in giving to us a series of pictures that, linked together, satisfies the reasoning faculty when we attempt to construct a cinema of the creation of the physical universe. At least, it indicates the enormous ages of stars, suggests the vast extent of the universe in time and space, and illumines its marvelous complexity.

**The Technique of Measuring Astronomical Space and Time.** Taking the light year as a satisfactory unit for expressing the dimensions of sidereal systems, let us consider the distances of neighboring stars and clusters, and briefly mention the methods of deducing their space positions. For nearby stellar objects we can make direct triangulation measurements of distance (parallax), using the earth's orbit or the sun's path through space as a base line. For many of the more distant stars, spectroscopic

methods are available—using the appearance of the stellar spectra to determine the real brightness of the stars, and measuring the apparent brightness directly. For certain types of stars too distant for spectroscopic data, there is still a chance of obtaining the distance by means of the photometric method. This method is particularly suited to studies of globular clusters. It consists, first, in determining, by some means, the real luminosity of a star, that is, its so-called absolute magnitude, and second, in measuring its apparent magnitude. Obviously, if a star of known real brightness is moved away to greater and greater distances, its apparent brightness decreases; hence, for such stars of known absolute magnitude, it is possible, using a simple formula, to determine the distance by measuring the apparent magnitude.

**Looking Backward Three Thousand Light Centuries.** By one method or the other, the distances of nearly five thousand individual stars in the solar neighborhood have now been determined; only a few are within ten light years of the sun. At a distance of about 130 light years we find the Hyades, the well-known cluster of naked eye stars; at a distance of 600 light years, according to Kapteyn's extensive investigations, we come to the group of blue stars in Orion, another physically organized cluster composed of giants in luminosity. At distances comparable to the above values we also find the Scorpio-Centaurus group, the Pleiades, and the stars of the Big Dipper.

Much greater distances have now been measured for globular clusters and faint variable stars. The Hercules cluster, at a distance of 34,000 light years, is one of the nearest of that remarkable class of objects. One-third of the globular systems now known are more distant than 100,000 light years; the most distant is nearly 200,000 light years away, and the diameter of the whole known system of globular clusters is about 300,000 light years.

**Enlarging Our Sense of Location.** Since the affiliation of the globular clusters with the galaxy is shown by their concentration toward the plane of the Milky Way and their symmetrical arrangement with respect to it, it also follows that the galactic system of stars is at least as large as this subordinate part. During recent years, we have found Cepheids (bodies of variable

luminosity discussed below) and other stars of high luminosity among the fifteenth-magnitude-stars of the galactic clouds; this can only mean that some parts of the clouds are more distant than the Hercules cluster. There seems to be good reason, therefore, to believe that the star-populated regions of the galactic system extend at least as far as the globular clusters.

**Location of the Solar System in the Stellar Universe.** One consequence of accepting the theory that clusters outline the form and extent of the galactic system, is that the sun is found to be very distant from the middle of the galaxy. It appears that we are not far from the center of a large cluster or cloud, but that cloud is about 50,000 light years from the galactic center. Twenty years ago, Newcomb remarked that the sun *appears* to be in the galactic plane because the Milky Way is a great circle—an encircling band of light—and that the sun also *appears* near the center of the universe because the star density falls off with the distance in all directions. But he concludes as follows:

“Ptolemy showed by evidence, which, from his standpoint, looked as sound as that which we have cited, that the earth was fixed in the center of the universe. May we not be the victims of some fallacy, as he was?”

Our present answer to Newcomb's question is that we have been victimized by restricted methods of measuring distance and by the chance position of the sun near the center of a subordinate system; we have been misled, by the consequent phenomena, into thinking that we are in the midst of things. In much the same way ancient man was misled by the rotation of the earth, with the consequent apparent daily motion of all heavenly bodies around the earth, into believing that even his little planet was the center of the universe.

**The Drift of the Solar System.** If man had reached his present intellectual position in a later geological era, he might not have been led to these vain conceits concerning his position in the physical universe, for the solar system is rapidly receding from the galactic plane, and is moving away from the center of the local cluster. If that motion remains unaltered in direction and amount, in a hundred million years or so the Milky Way will be quite different from an encircling band of star clouds;

the local cluster will be a distant object, and the star density will no longer decrease with distance from the sun in all directions. It is not inconsistent with what we know now about the stellar universe to conceive that the earth's astronomers a hundred million years hence may look out on one side to the great galaxy through which the solar system is now passing; and on the other side to other galactic systems which now are not within the vision of our telescopes.

### **An Enlarged Conception of Evolution**

**The Astronomer's View of Progressive Change.** Although direct observation has never been made of the evolving of a luminous star out of primordial nebula, astronomers, nevertheless, by scientific inference and repeated tests of their working hypotheses, have come to believe that the circumstantial evidence for such a development can be accepted as proof. On that basis they have reached a number of generally accepted conclusions.

The stars are highly organized, spheroidal masses of exceedingly hot, luminous gases. The diffuse nebulae from which stars are supposed to have evolved are, in general, disorganized or unorganized masses of gas, sometimes luminous, sometimes not. The luminosity of a star such as the sun is due to the high temperature of its constituent gases. Some of the luminosity of the diffuse nebulae is probably due to the reflection of starlight (in the same way as zodiacal light represents the reflection of the sunlight from small particles in the solar system), and some to a phosphorescent kind of radiation, excited by neighboring stars in the atoms and molecules of the gases that are known to exist in these nebulae.

The stars differ little in form, but greatly in size, and still more remarkably in the character of the light they emit. Diversity in size and light appears to depend largely on the length of the time that has elapsed since the hypothetical organization out of nebulosity.

**The Prevailing Theory of Orderly Change in Stars.** The prevailing theory at the present time pictures the newborn star of enormous dimensions, with a low temperature at its surface,

and a feeble luminosity. It differs little from a nebula—it is merely at an early stage in condensation. As the new star grows in age it shrinks in size. In operating under gravitation, maturity means high density rather than great stature; and youth is the stage of rarity, therefore of monstrous dimensions. As the “growing” star contracts, the falling together of its various parts generates heat. The heat from this and other sources is radiated away from the surface, and the star tends to cool. This act of cooling, by losing the heat of radiation, brings about further contraction, an increase in the internal density, with the further generation of heat. The final result sounds paradoxical. The more heat the young gaseous star radiates away, the more heat it acquires, and the temperature at the surface steadily increases throughout the first stages of its long life history.

**Changing Temperature and Spectrum of Stars.** At the low temperature possessed by a star when it makes its first steps in luminosity, the surface has a reddish appearance. If the astronomer analyzes the light with a spectroscope he finds radiation characteristic of certain chemical elements. With increasing contraction and temperature, the average color changes to orange, then to yellow, green, blue; other characteristics of the spectrum change as well. When the star shines as a reddish young giant the surface temperature is about 4,000 degrees Centigrade. When later it becomes yellowish the temperature lies between 6,000 and 8,000 degrees; and the bluish-white stars radiate with temperatures from 12,000 to 20,000 degrees or higher.

**Changing Density and Specific Gravity.** The density, or specific gravity, of the contracting star, of course, steadily increases. Beginning with a rarity much less on the average than that of the best vacuum obtainable in a terrestrial laboratory, the average density increases to about one-tenth that of water for the highly luminous stars. Now from that stage, in its contractional life history, the star loses heat by radiation faster than it is generated. As a result, the surface temperature begins to fall off, the total brightness begins to decrease; the star passes the prime of life and starts down a decline.

We call the stars giants while they are in that part of their career where surface temperature increases. We call them dwarfs

throughout the decline toward senility and extinction. The declining dwarf star runs through the series of colors and spectral characteristics in the inverse order, from blue to green, to yellow, orange, red.

Our sun is a yellowish star in the dwarf stage, apparently far past the turning-point in its life history.

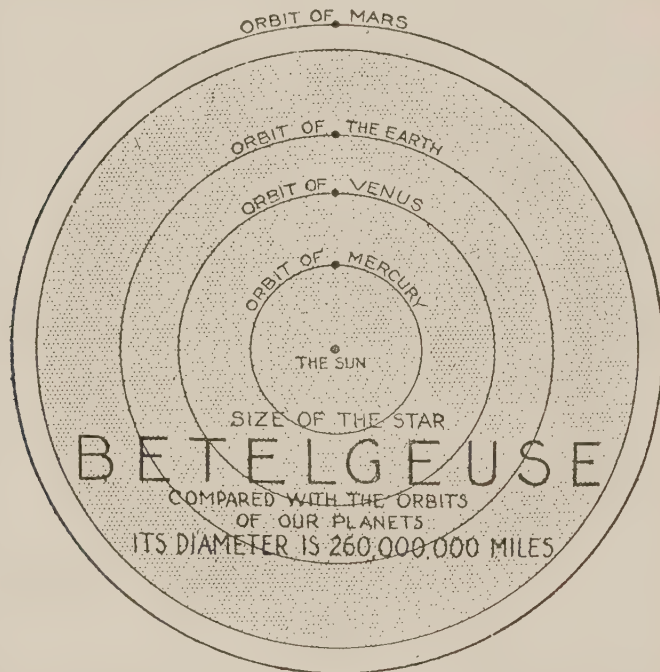


Figure 17. The Diameter of Betelgeuse. The shaded portion of the diagram shows the size of Betelgeuse compared with the orbits of our inner planets. The sizes of the sun and planets as shown here are greatly exaggerated; the sun, if drawn to scale, would be only  $1/150$  of an inch in diameter. (Courtesy of the *New York Times*.)

**The Sizes of Stars.** The diameter of the sun is a little less than a million miles. We have not yet measured directly or indirectly the diameters of red dwarf stars but a few of the yellowish dwarf stars are known to have dimensions comparable with those of our sun. The dimensions of the components of large numbers of bluish-white double stars have been estimated, from mathematical analyses of their orbits, to be from two to

twenty times the solar diameter. It is, however, only among the red and the yellow giant stars that striking dimensions are encountered. Theory, as well as the experiments with the interferometer as applied by Michelson and Pease at Mount Wilson, shows the great size of the giant stars. The interferometer, for instance, has measured the angular diameter of Betelgeuse, a bright reddish star in Orion. The distance of the star has been measured trigonometrically; combining these two data, distance and angular diameter, it is simple to compute that the linear diameter of Betelgeuse is more than 200 million miles—considerably greater than the diameter of the orbit of the earth. The space occupied by that star is therefore much more than ten million times the space occupied by the sun.

The red star Antares, in Scorpio, has been found to be of still greater size; and on theoretical grounds, a considerable number of distant stars that appear exceedingly faint in our biggest telescopes are believed to be as large or larger.

### QUESTIONNAIRE WITH READING REFERENCES

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## CHAPTER VI

### NEWER CONCEPTIONS OF THE SIDEREAL UNIVERSE \*

#### **The Astrophysical Universe**

**The Source of Stellar Energy.** The origin of the heat that the sun radiates wantonly upon the earth has long been a subject for speculation and investigation. Clearly the simple combustion of the matter the sun is composed of would be quite insufficient. The earth intercepts less than one billionth part of the solar radiation, and of the fraction of that billionth part that gets through our atmosphere, only a very minute fraction is utilized by terrestrial organisms. The total daily output of energy from the sun is obviously enormous, and the interval during which the sun has radiated is beyond expression in days. Our theories of the origin of radiant energy must therefore account for a vast store in the sun and other stars.

**Source of Solar Heat.** The names of Helmholtz, Lane, and Ritter have been associated with the theory of the gravitational source of solar heat. The Helmholtzian hypothesis that the gravitational contraction of the sun supplies ample energy for radiation has been generally maintained until recently. That source now appears to be secondary, but the gravitational mechanism is probably an important regulatory device for the control of the radiating energy, which comes, not from the gravitational infall of the atoms of the gases that make the star, but chiefly from the energy within the atoms themselves. The forsaking of the Helmholtzian theory is made necessary by the newer conception of the extent of the sidereal universe. The gravitational hypothesis would be sufficient if we were content to limit the age of the sun (radiating at its present rate) to a few million years. Helmholtz and others long ago computed that the energy derivable from

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\* By Professor Harlow Shapley (see note at beginning of Chapter V).

contraction could support the observed output for an interval of ten to fifty million years. But now at least three lines of evidence from three different sciences indicate that the present solar rate has been maintained for a much longer interval—viz., the evidences offered by the geologist, by the physicist and by the astronomer.

**The Gravitation Theory Challenged—Side-Lights from the Sciences.** The evidences coming from the fields of geology and physics are presented at length by Professors Lane and Kent in chapters that follow. In this place it is needful to discuss them only briefly. It is generally admitted that the sun has advanced very little in age during the whole interval of historic geology. For instance, certain animal forms common in the Paleozoic times are unchanged in essentials today. The terrestrial temperature has, of course, oscillated slightly throughout geological ages; local surface temperatures have varied greatly with the elevations and depressions caused by the bendings of the earth's crust in the shrinking process; but the average temperature must have remained nearly constant during the evolution of metazoan organisms.

**Evidence Educued by the Geologist.** If we measure present rates of denudation and erosion, present rates of sedimentation, present rates of deposition of salts in the sea, we can estimate the whole duration of geological times. Barrell, Chamberlin, Holmes, and others have recently pointed out, however, that present rates are deceptive. We are living in an age of great land elevation. The *average* rate of geological processes is undoubtedly much slower than the present rate. Moreover, there have been long intervals of time when the processes have nearly or completely come to a standstill. Taking this into account in his "Theory of Rhythms," Barrell is led to conclude that the age of the Paleozoic fossils is to be measured in hundreds of millions of years. This result is clearly in opposition to the Helmholtz-Kelvin deductions.

**Evidence Educued by the Physicist.** The physics of the last two decades has contributed an instrument important for the measurement of geological ages, and hence of value in the meas-

urement of solar evolution and in the search for the true source of solar power. This physical device is based on our knowledge of the behavior of radioactive elements in the rocks. The speed with which the elements uranium and thorium automatically decay, and resolve themselves ultimately into the inert gas, helium, and the common element, lead, is known with considerable accuracy. By measuring, for instance, the relative amounts of uranium and lead remaining in radioactive minerals of various geological epochs, it has proved feasible to date these epochs—to set up a time scale for the whole of geological history. The radioactive minerals appear in many formations all over the earth's surface, and have been extensively studied in recent years. According to this method, the earliest known pre-Cambrian rocks date from more than 1,000 million years ago, and the beginnings of the fossil-bearing Cambrian formations are over 500 million years old. This result from physics, therefore, also clearly disagrees with the contraction theory of the source of solar (and of stellar) energy.

**The Astronomer's Contribution.** The astronomer's contribution to the problem is equally definite. The mathematical theory of the evolution of a gigantic mass of luminous gas has led, in the hands of Eddington and Jeans, to a remarkable knowledge of the interior of a star. For the present, the most significant deduction from that work is that such a gaseous body will run through the giant stage of its evolution in a few thousand years if the energy for radiation comes solely from the gravitational infall of its parts. Studies of globular star clusters and of giant variable stars both give evidence of longer life for the giant stage.

**Results of Study of Globular Star Clusters.** Work on the globular star clusters with the large reflecting telescopes at Mount Wilson has brought out the interesting fact that these remote systems are composed of just such giant stars as Eddington's theory analyzes. Because the velocity of light is finite, the more distant of these clusters are (as far as our earth-made records go) much younger than the nearest clusters. Their recent history is still en route as light-waves. The system N.G.C. 7006, the remotest star cluster on record at the present time (1930), is,

for us, nearly 200,000 years younger than the great cluster in Hercules. My analysis of the giant stars in both systems shows, however, no evidence of different ages. The same result is found from the study of many other clusters.

We have no reason to believe, of course, that the more distant clusters came into existence later than the nearer ones; it would be preposterous to think that distance from our earth has anything to do with the order of origin. Hence, this similarity in near and distant clusters must mean that an interval of one or two hundred thousand years is not sufficiently long for a measurable evolution of giant stars. We must conclude, therefore, because of the clear implications of the mathematical theory, that the radiant energy of a giant star comes not from gravitation alone.

**Results of Study of Giant Variable Stars.** The variable stars, called Cepheids (because the star Delta in Cepheus was the first known example) owe their oscillations in brightness to pulsations, according to the theory advanced some years ago by the present writer. These pulsations, with their consequent variations in light, are periodic, the period or interval of time between successive geyserlike outbursts depending on the density of the star. Recently it has been shown that the pulsations of Delta Cephei could not have been maintained at a constant period as observed for a century unless its radiant heat is generated by something more than gravitation.

**How the Energy of Atoms Is Used.** Science is not yet ready to describe how the stars use the energy of the atoms. In a few years we shall no doubt be able to speak more advisedly on the subject. At present we surmise that the building up of the heavier chemical elements, such as iron, lead, and gold, out of the lighter elements, such as hydrogen and helium, releases energy for stellar radiation. There appears to be a transformation of a part of the mass of hydrogen atoms into energy when that fundamental material is compounded into more complex elements. The energy that stars shine by, and which as a passing incident animates the earthly plants and animals, appears, therefore, to be a by-product of the material evolution of cosmic gases.

## The Solar and Other Planetary Systems

**Older Conceptions of Their Origin.** Serious attempts have been made to set up a natural explanation of the origin of the

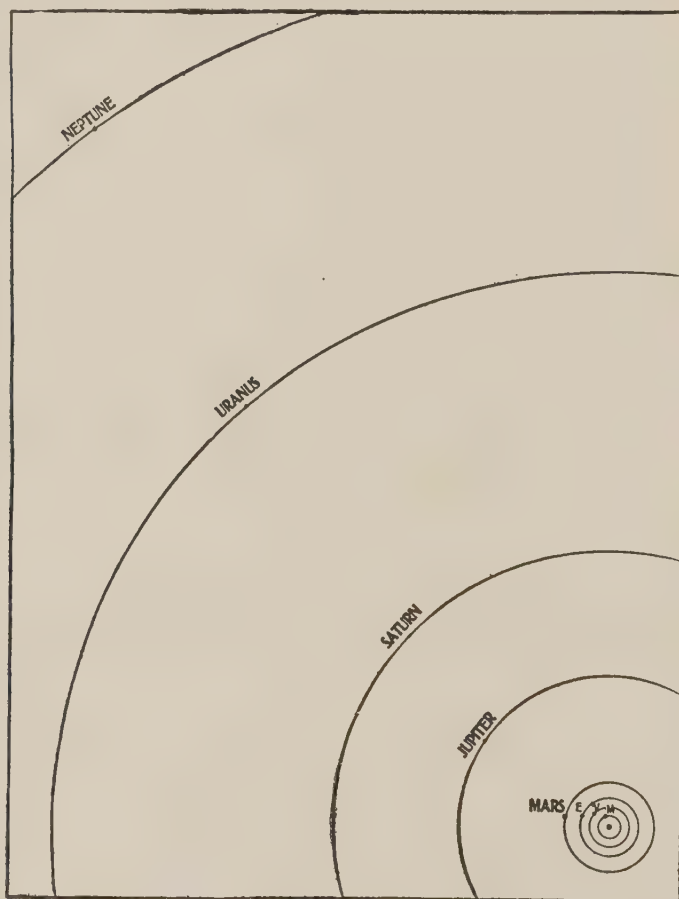


Figure 18. The Solar System. The orbits of the planets are drawn to scale. The asteroids (minor planets) travel round the Sun in orbits that lie, in general, between those of Mars and Jupiter. The diameter of the orbit of the Earth is 185,000,000 miles.

earth and the other planets of the solar system, in the place of the earlier supernatural accounts. These attempts followed as

a matter of course the acceptance of the Copernican theory. The deservedly famous hypothesis of La Place, more or less coinciding with similar explanations by Thomas Wright, Immanuel Kant and others, held its place in scientific thought for a century. This hypothesis is now generally abandoned by astronomers. Its attempt to account for the origin of planets from cast-off rings of a condensing, rotating nebula fails to meet the demands of reasoning in certain dynamical details. The present speed of rotation of the sun on the one hand, and the distances and velocities of the planets on the other, are mutually irreconcilable in the La Placian scheme.

**The Planetesimal Theory.** The planetesimal theory proposed by Chamberlin and Moulton, and the subsequent varia-

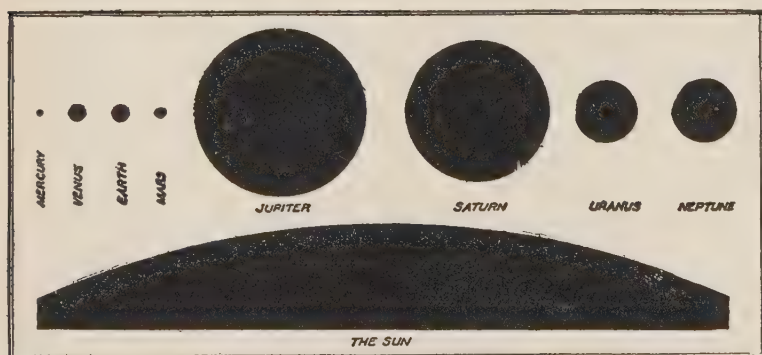


Figure 19. Relative Dimensions of the Sun and Planets. (From Moulton.)

tions upon it, have led to a conception of the origin of the planetary system that is compatible both with the demands of celestial mechanics and with those of sidereal probability. Difficulties are found with all proposals. But the so-called tidal-evolution theory, which deviates in detail and method rather than in principle from the planetesimal hypothesis, is at present considered to be reasonably satisfactory. It differs from the nebular hypothesis in many ways, but most conspicuously in deriving the planets from the sun through an accident, rather than through a natural process of contraction.

**The Tidal-Evolution Theory.** According to the tidal-evolution theory, the planets originate from the sun as products of eruption, of solar catastrophe, incited by the passing of another sidereal body. They represent the débris of a disaster that occurred some thousands of millions of years ago. When two stars wandering in space come near together, the mutual gravitational attraction raises tides upon them both. The case is analogous to terrestrial tides, generated by moon and sun; but the greater masses involved in stars raise relatively higher tides, which, in a sufficiently close encounter, must become unstable and break down, causing the gaseous stellar matter to fly out in streams. For the solar system, the ejecta were apparently concentrated in a few large masses which now appear as the planets. Assuming such an origin, Jeffreys has computed that the present shape of the orbits of the planets indicates that the genesis of the sun's planetary system occurred not less than 2,000 million years ago.

Presumably the disturbing star which we must thank for our present existence was reciprocally disturbed at the time of the encounter. What happened to it depended on its mass, its stage of evolution, and its velocity of rotation at that time. We have no clue to the identity of this hypothetical object. It has had sufficient time since the affair with our sun to be lost in the depths of space.

**Formation of Planetary Crusts.** The planets, born of the sun, are made of the same chemical constituents. The earth, originally gaseous, being of relatively small mass, has cooled and formed a solid crust. Meanwhile, no doubt, it has picked up a certain amount of the surrounding fragments. Even now, in the form of meteors and meteorites, the earth and the other planets are picking up small gleanings that may date from ancient times.

Some of the other planets—Mercury, Venus, Mars—have also formed superficial crusts; but the planets of greater mass—Jupiter, Saturn, Uranus, Neptune—apparently still partially retain their gaseous nature. The average density of Saturn is even less than the average density of its solar parent, but it is much denser than the outer layers of the sun.

## Life and the Physical Universe

**Probability of Non-Solar Planets.** We have suggested above that other stars may have planetary systems. We often wonder if some of those planetary systems are analogous to our own—if other planets are similar to the earth—if terrestrial life exists elsewhere in the universe. We often contemplate this, and ponder, for there is little else that we can do about it. It is exceedingly far beyond our telescopic power to detect visually other planetary systems. As reflectors of light, stellar planets are of no consequence at stellar distances. As gravitational disturbers of the motion of their primary suns, they are essentially weaklings. We cannot prove the existence of a single non-solar planet. Yet we infer, with cause, that they exist.

**Possibilities of Life on Planets Other Than the Earth.** For the sake of furnishing material for contemplation, one can reasonably assume that there are among the thousands of millions of known stars a great many with attendant planets. Indeed, the chances favor the existence of some planets especially suited to some kind of unstable chemical evolution which we might call life, and, for all we know, that development may sometimes be very high compared with ours. But the chance that terrestrial forms of life are duplicated, or closely paralleled, is much more remote. And that there now exists an organism of the exact physical and chemical character as the predominating terrestrial primate is asking too much of the law of chance, even in a sidereal system as large as we know ours to be, for the existence of man depends on a delicate balance of physical conditions and laws. The astronomer can emphasize a few of the factors absolutely essential to life of the terrestrial type.

**Planetary Conditions Essential to Life.** In the first place, the abode of life must be near a source of energy—a star. The star must not be double; otherwise a sufficiently stable planetary orbit could not exist. The single star must have had its planet-breeding disturbance to just the right degree. Once disturbed, it must be left in peace for an enormous interval of time; it cannot have passed through a nebula, or in any other way flashed

up as a nova, if the delicate animate evolution on its planets is to avoid fatal interruption.

The planet that is to give birth to organisms must be neither too large nor too small. If too massive, its meteorological phenomena (rainfall, windstorms) would be of too violent a nature

Name and symbol	Number of satellites	Apparent angular diameter (equatorial)	Mean diameter in miles	Mass $\oplus = 1$	Density water = 1	Gravity at surface $\oplus = 1$
Sun $\odot$ .....	...	31' 59" .3 (mean)	864,100	331.950	1.41	27.89
Mercury $\text{♁}$ .....	0	4" .7 to 12" .9	3,194	0.04	3.8	0.27
Venus $\text{♀}$ .....	0	9" .9 to 64" .0	7,842	0.81	4.86	0.85
Earth $\oplus$ .....	1		7,927	1.000	5.52	1.00
Mars $\text{♂}$ .....	2	3" .5 to 25" .1	4,250	0.108	3.96	0.38
Ceres $\text{♁}$ .....	0	0.27" to 0.69"	478	1/8,000?	3.3?	0.037?
Jupiter $\text{♃}$ .....	9	30" .5 to 40" .8	86,499	316.94	1.34	2.64
Saturn $\text{♄}$ .....	9	14" .7 to 20" .5	71,337	94.9	0.71	1.17
Uranus $\text{♅}$ .....	4	3" .4 to 4" .2	33,183	14.66	1.27	0.92
Neptune $\text{♆}$ .....	1	2" .2 to 2" .4	30,884	17.16	1.58	1.12
Moon $\text{♁}$ .....	0	31' 5" (mean)	2,160	1/81.56	3.33	0.165

Name	Mean radius of orbit; millions of miles	Eccentricity	Inclination of orbit to elliptic	Sidereal period in mean solar time	
				Orbital revolution in days	Axial rotation
Mercury...	35.9	0.20562	7° 00' 12"	87.96926	88.0 <sup>d</sup>
Venus.....	67.2	0.00681	3 23 38	224.7008	
Earth.....	92.9	0.01674	0 00 00	365.2564	23 <sup>h</sup> 56 <sup>m</sup> 4.09 <sup>s</sup>
Mars.....	141.5	0.09333	1 51 01	686.9797	24 <sup>h</sup> 37 <sup>m</sup> 22.58 <sup>s</sup>
Ceres.....	257.0	0.07653	10 36 56	1,681.449	
Jupiter.....	483.2	0.04837	1 18 28	4,332.588	9 <sup>h</sup> 50 <sup>m</sup> to 9 <sup>h</sup> 55 <sup>m</sup>
Saturn.....	885.9	0.05582	2 29 29	10,759.201	10 <sup>h</sup> 14 <sup>m</sup> to 10 <sup>h</sup> 38.5 <sup>m</sup>
Uranus.....	1,782.2	0.04710	0 46 22	30,685.93	10.7 <sup>h</sup>
Neptune.....	2,792.6	0.00855	1 46 38	60,187.64	15 <sup>h</sup> ?
Moon.....	238,857*	0.05490	5 08 40	27.3217	27 <sup>d</sup> 7 <sup>h</sup> 43 <sup>m</sup> 11.5 <sup>s</sup>

\*Miles.

Figure 20. Principal Data of the Solar System

for earthlike life. If its mass is too small, it cannot retain an atmosphere. Earthly creatures, for instance, could exist neither on massive Jupiter nor on the Moon.

The favorable planet must have an atmosphere of the proper density and constituents. Its crust must have a salutary chemical constitution. Probably most important of all it must possess

water in a liquid state, because that is essential to the protoplasm that is the basis of life. Therefore, the planet must be at an appropriate distance from the sun. At the too small distance of Mercury the temperature is too high. At the too great distance of Saturn the water would be in a solid form. Other restrictions involve the rotation period of the planet, the inclination of its axis, and the eccentricity of its orbit.

**Narrow Range of Probability That Terrestrial Types of Life Exist Elsewhere.** To sum up, astrophysics and astrochemistry place the possibility of earthlike life within narrow bounds—so narrow, indeed, that we are forced to believe that if any protoplasmic life exists on other planets in our solar system, it must be of the lowest form. And our only justification for believing it exists elsewhere in the stellar universe is that space is great, stars are many, and time is long.

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## CHAPTER VII

### OUR SPHERE—THE EARTH \*

**Geology—as a Branch of Cosmology.** Grabau, in his introduction to geology says: “In its broadest sense . . . geology is the science of the earth and all that pertains to it.” Bringing this into perspective, he goes on: “It is the study in detail of one of the planets of the solar system, by the inhabitants of that planet, who are themselves a part of it. . . . And thus we may consider that the study of the physical universe, i.e., the *cosmos*, which may be called the science of cosmology, has only two primary divisions, astronomy and geology. This may be summarized as follows:

COSMOLOGY, the science of the universe	{ <ol style="list-style-type: none"><li>1. <i>Astronomy</i>—The science of all the heavenly bodies, including the earth, their character, description, interrelations, movements, etc., and the laws which govern them.</li><li>2. <i>Geology</i>—The science which deals with the material, structure, history, etc., of one of these bodies, i.e., the earth.”</li></ol>
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**Correlations of Geological Sciences.** “Such a view of the science of geology gives it an extremely comprehensive scope, and we must recognize that in ordinary parlance the term is used in a much more restricted sense. Nevertheless, it is desirable to take this comprehensive view at the outset, and to note the several subdivisions into which such a broad science naturally falls . . . with all of which the student of any one division should have at least a general acquaintance.”

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**Cosmic or "Astronomical" Geology.** Approached from this broad angle, there is an aspect of the general science of geology called cosmic or "astronomical." This is the connecting link between geology in its more limited field, and cosmology and astronomy. The link is important not alone to the specialized student of geology as a means of gaining perspective; it is important also to students of all of the other natural sciences, and quite as needful to straight thinking about the conditions that affect our day-to-day lives. How else could we know the true meaning of winds, weather, tides, gravitation, heat, light, darkness, and countless other things which enter into our thinking about problems of adjustment?

**"Terrestrial" Geology—Its Subdivisions or Special Fields.** Having marked off a special aspect of geological inquiry as astronomical, consistency would require that we have a distinguishing name for that which remains. We might call it "terrestrial." However, what remains usually goes by the name "geology" or "general" geology, to indicate that the author or speaker is not dealing with a geological specialization. A general text on geology deals more largely with data taken from the earth itself, and the phenomena occurring at or near the earth's surface. This "general" field has been subdivided into many parts for purposes of research. As is the case with all descriptive sciences, the more exact knowledge we come to have, the more inclined we are to follow a special interest. Seeking to arrange in pigeonholes the many newly discovered facts, the result is to enlarge the fund of information relating to each of the related subjects.

One of the most fundamental subdivisions of the field of geology has been that which treats data of one kind as relating to earth *structure*, and those of another as relating to *activities*. On the one hand are data referring to conditions that are called "static"; on the other hand, phenomena to be explained as the result of an interplay of forces called "dynamic." In general, the first group of scientific observations is classified and brought together under the broadly descriptive title of "structural" geology. The more general science dealing with the order and relative position of the earth's crust is called stratigraphy; this,

however, becomes specialized in various ways and among the related limited sciences we may list paleontology, mineralogy, petrography, lithology, etc. The sciences dealing with dynamic phenomena are many—among which we may list aereology, meteorology, oceanography, seismology, and seismography.

Besides these, there are various geological fields which, in their practical applications, combine both the static and the dynamic. Among these may be listed the sciences of geography (historic, political, social, industrial, commercial), determinative mineralogy, economic geology (subdivided in many ways, such as agricultural, mineralogical, etc.). Furthermore, there are specialized sciences which bear more directly on, or which more largely utilize the result of inquiries in allied scientific fields—such as mathematics, chemistry, physics, and biology. Among these may be noted geometric crystallography, physical crystallography, mathematical crystallography, biological geology (paleobotany and zoölogy), paleontological geography, etc.

## The Earth and Man as Seen in Perspective by the Geologist

**The Earth Viewed As a Stage.** The foregoing is said, by way of "orientation," before enlarging on subjects of special interest to the geologist in his dealings with those balanced and conflicting forces of which we are made aware in the several parts of his field of research. We may approach this task thus: When seeking to picture in the mind the complex phenomena and data that are to be set in orderly arrangement, one method is to think of the earth's surface as a stage. Here is where that part of the great cosmic drama, in which the interests of man centers, is being enacted. The analogy is striking. All drama is a "staged" conflict in which the actors impersonate contending forces—energies out of balance. Objects not in motion give setting to the actors; all objects and forces in balance constitute the scenery. The drama is a picturesque representation of dynamic forces that converge in human interests or objectives. The problem of the dramatist is to reveal what the dynamic forces are and to interpret their significance—to show how the conflicts thus portrayed are being harmonized, or, failing in this, what the result is. Thus, he forecasts or explains changes in the established order.

**The Cosmic Forces in Conflict.** In like manner, the historian portrays wars as the dramas of an unbalanced civilization. For his purpose he sets forth the significance of movements which take place on a territorial frontier where two or more hostile human organizations meet. It is in this same sense that the earth's surface is thought of as the stage or frontier where cosmic forces collide—forces that enter into and determine geological movement and resulting earth-order. It is here on the earth's surface that we find the evidences of continued warfare. But to understand the significance of what is now going on, we must have knowledge of past "acts" as well as present; we must see with our mind's eye the dramatic movement; we must think in terms of beginnings as well as what is now being acted; the earth-drama must be thought of as beginning far back in cosmic evolution.

So presented, or dramatized, each of the "ages" is thought of by the geologist as turning on the interplay of two kinds of forces: (1) forces within the earth; and (2) forces without. One set of dynamic forces is inside the earth's crust; quite other forces surround and are brought to bear upon this barrier. In a sense, we may think of the earth's surface structure as the material elements that make up the scenery of the drama. It may be more illuminating, however, to use the war analogy, and think of the earthworks that appear upon the earth's crust as ramparts—entrenchments that stand between the forces within and without. At times and at points this line of defence may be pushed out, or drawn in, or quite generally reorganized. At all times the earth's crust is being acted upon externally by eroding elements. For historic purposes, the earth's crust may be viewed as an ancient battlefield which may be examined and studied for evidences of past conflicts.

**Two Kinds of Forces at Work.** The geologist sees these forces at work; and he undertakes to correlate them. Because the forces within operate to throw up great ridges (mountain ranges, volcanoes, etc.) and elevate continents, they are called *the forces of elevation*. The phenomena by which external forces are made known are less spectacular but more continuous—they consist of changes wrought directly and indirectly by the sun's

heat. We think of them as changes wrought by freezing and thawing, wind, rain, stream, ocean current, light, and by the upsetting, unbalanced, disintegrating capacities of living things. These the geologist calls *forces of degradation*. They are the forces that "drag down Eonian hills and sow the dust of continents to be." Operating alone, there is nothing dramatic about them; but they are the most powerful agencies with which the geologist deals.

**Energy from the Sun.** The sun endows the earth with a continual stream of energy in the form of heat and light. This

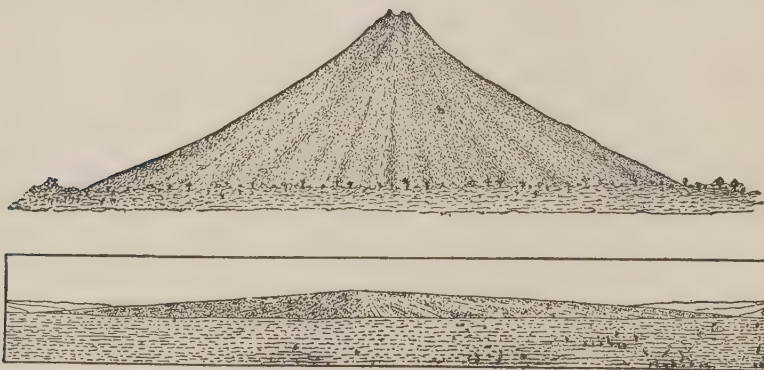


Figure 21. Volcanic Cones—Cinder Cone (above) and Lava Cone (below).  
(From Pirsson and Schuchert.)

is transformed and transmitted in various ways—through such media as ether and atmosphere, rising vapors and moving clouds, air strata of differing temperature and density, discharges of electricity, etc. The sun lifts and holds in atmospheric suspension above our heads a ponderous vaporous sea—raised by the sun's heat in the form of vapor. A condensation of this vapor in an air stratum, due to cooling, may at any time or place precipitate a flood—which in turn may course down slopes or, being drunk up by the porous earth, reappear at lower levels as springs. The energy of the sun that raised the vapor thus passes into storm and stream; and these wash down the *débris* of disintegrated rocks, the silt and sand, into the sea; as water percolates, a chemical disintegration goes on; in freezing and thawing, a physical disintegrating process of enormous force is at work; in the reactions

and adjustments of plant and animal life, the surface materials are changed. Such are some of the forces which the sun brings to bear upon the earth's crust.

**Resulting Changes—A History.** This geological drama is an ever-changing movement in which there are no rehearsals or reenactments of pre-existing order. Geological ages are "his-



Figure 22. Earth Pillars Left by Weathering of Moraine Stuff, Tyrol.  
(From Geikie.)

stories." In the rocks is written the long continued story of the earth. In them also is written the story of life. It is an indelible record of past events. To read it requires only that we learn the language of nature and acquire the wisdom to interpret the meaning which it has for us. It is not simple. To read we must delve deep. And in making inferences we cannot assume that the forces operate singly or simply. Usually forces within and forces without combine. For example: The power of the tide-mill comes from the initial spin of the earth; but the condition

that gives rise to this power is the presence of the moon and the sun operating upon our spinning sphere. The initial heat of the earth is one source of energy, its energy of rotation another, and the elevation of the earth's surface is supposed to be due to a continued loss of initial energy. The sun, however, furnishes a million times more heat to the surface exposed than comes from the inside, but this is an alternating heat. Every minute the sun pours on each square centimeter of earth surface directly exposed to its rays enough heat to raise a cubic centimeter of water  $2^{\circ}$  C., whereas it would take a year to generate as much heat on the earth's surface from the inside. Thus, practically all the weathering of rocks, "the work of time" (rivers, wind, etc.), depends on the sun. The waves of the sea and the changes wrought upon the earth's surface by living things are also differing expressions of energy coming to the earth from the sun.

### **The Geologist's Interpretation of Events Recorded**

**Observation and Inference.** To read the order of geological events and gain an understanding of the nature of the earth's crust, the geologist begins by studying present activities—he observes present phenomena. The present is his key to the past. He finds all these activities leaving their traces like footprints on the sands of time. Then making use of that "scientific imagination" which Tyndall has emphasized, he finds signs of actions similar to those studied—traces of processes like the present in the past. He finds caves plainly cut by ancient seas in places far above present sea level; he finds extinct volcanoes, like Crater Lake, Oregon; he finds gorges cut by rivers, where now no rivers exist; he finds valleys like that of the Red River of the North that give evidence of having been bottoms of former great lakes or of much larger streams flowing in an opposite direction.

**The Geologist's Measure of Time.** Reading the earth's history backward, the geologist gradually comes to have a conception of the time required for the changes recorded in the rocks. Beginning with his study of the rate of present activities he computes how much time must have been required to produce these

relics of the past. The more important observations which form the basis for such calculations are of three kinds: (1) the observed rates of erosion and of sedimentary deposition; (2) the rates of atomic change in radioactive substances; and (3) the rates of accumulation and concentration, for instance of salt. Great Salt Lake in Utah and Pyramid and Winnemucca Lakes

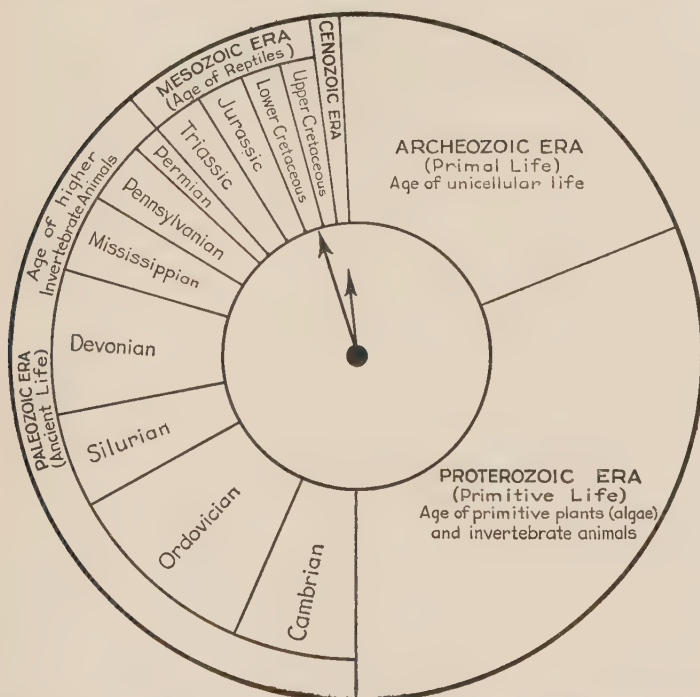


Figure 23. Geologic Time Clock. (Courtesy of the *Scientific Monthly*.)

in Nevada are evidently but shrunk remnants of vastly larger lakes. Recently Professor Jones of Reno, Nevada, computed the time necessary to dry up the former Lake Lahontan to the present Pyramid and Winnemucca Lakes. He also computed the time required to accumulate the salt that these waters contain—comparing their greater saltiness now with tests made thirty-one years ago. He also calculated the amount supplied by the rivers which empty into it. Using his various methods, the con-

clusion is reached that from two thousand to five thousand years must have elapsed since these were fresh water lakes—i.e., since the change took place that converted them into land-locked basins.

**Joly's and Clarke's Estimates.** By a similar method, Joly first estimated the time required for the ocean to accumulate its sodium. Recently Clarke has gone over the calculation with fuller data and arrived at a result not differing 10 per cent.<sup>1</sup> The conclusion is that it would take something like one hundred million years, at anything like present rates, to accumulate the sodium in the ocean—to account for which it is estimated that this much sodium might have been furnished by the breaking down, decomposition, and leaching out of a layer of igneous rock half a mile in depth. But for the purpose of these calculations it was necessary to make certain assumptions about the rate of decomposition—assumptions that in some respects are certainly not strictly true. The present is assumed as the average for the past—although it is thought that the rate of activity has not been the same throughout the past. Moreover, an analysis of river water not being taken in time of flood may overestimate the amount of salts furnished by the river.

**Variations to Be Taken into Account.** Thus, on these calculations certain critical and corrective judgments have to be made before they can be applied over a period that reaches back from the present to a past in which it is assumed the activities studied had their beginning. If, for instance, the initial Lake Lahontan contained salt, as it doubtless did in some quantity, some deduction must be made from the estimated time required to evaporate the water collected in Pyramid Lake. The same correction must be reckoned with when calculating the age of the ocean. Another element in these calculations must be considered: the conditions, in all probability, have not remained the same. We have every reason to believe that the rates of geological activities have varied in the past for there have been great climatic changes. We have reason to believe that less than twenty thousand years ago Canada and Scandinavia were swathed in ice, while imprints of leaves of magnolias and sequoias on rocks from Spitzbergen indicate that in a remoter past there was a warm

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<sup>1</sup> U.S.G.S. Bulletin, 770.

climate far north. With these changes in climate there must have been extensive changes in the rapidity of many processes.

### Some Dynamic Aspects of Terrestrial Order

**The Swinging Movement and Its Relation to Temperature and Life.** Climate depends upon a varying balance between heat received and heat lost; and the order of the seasons depends upon this changing remainder of heat as the earth pursues her elliptic path around the sun. Yet the shifting of that balance and the oscillations of climate have not gone so far since life has left its traces on the earth as to wipe it out—i.e., on all parts of the earth at the same time. This means that the cold has never reached the cold of the space between us and the moon. The relative equability of temperature is such a marvelous illustration of order and balance that I cannot forbear dwelling upon it. Although the earth is swinging through space which is near absolute zero, and the atmosphere is more than  $50^{\circ}$  C. below freezing less than ten miles above us; although it is red hot ( $600^{\circ}$  C.) less than fifteen miles below; although heat comes to us from the sun whose surface is at  $6,000^{\circ}$  C.—yet the varying energies producing these conditions have been so balanced and ordered that the temperature of the earth has been such that living things could exist and develop; the temperature of the surface of the earth has then always been somewhere between  $0^{\circ}$  C. and  $100^{\circ}$  C., freezing and boiling—throughout many millions, very likely a thousand millions, of years.

**Periodic Changes—The Cycle.** Now all the forces that vary as do those that vary with the season, may be called periodic. If in a periodic action we know the range (the amount of change), the period from one high point to the next and the epoch of any of these periods, we have the essential factors of the cycle. We need assume neither beginning nor end. But there are two other kinds of processes or activities to be thought about, analyzed, or interpreted: (1) the “progressive” process or irreversible activity; and (2) processes or activities which are like a cracking or giving way—the “paroxysmal” or miraculous.

**Changes That Are Progressive.** There are six "progressive" forces or activities that have been made the subjects of systematic


Showing Conditions in Europe during the Development of Man Adapted from Osborn's 'Men of the Old Stone Age'				
Time	Climate COLD WARM	Animals	Implements	Human races
Postglacial 25,000 years		Deer, bison, horse, chamois, ibex	Iron 1000 B.C. Bronze 1000 yrs. Pottery Polished stone 5000 yrs.	Homo sapiens Brain capacity 2000 cc. Cro-magnon Race Brain capacity 1800 cc.
4. Glacial Period 25,000 years		Reindeer, arctic fox, muskox		
3. Interglacial Period 100,000 years		Bison, horse, hippopotamus, elephant, lion, rhinoceros, sabre-tooth tiger.	Carving, painting  Clipped flints 25,000 yrs.  Rough flints 25,000 yrs.	Neanderthal Race Brain capacity 1600 cc.  Piltdown Race Brain capacity 1400 cc.
1. Glacial Period 25,000 years		Reindeer, wooly mammoth		
2. Interglacial Period 200,000 years		Hippopotamus, rhinoceros, elephant, stag, bison, horse		Heidelberg Race
2. Glacial Period 25,000 years		Reindeer, wooly mammoth.		
1. Interglacial Period 75,000 years		Hippopotamus, elephant, rhinoceros.	(Eoliths?)	
1. Glacial Period 25,000 years		Muskox in England.		(Trinil race lived in Java) Brain capacity 900 cc.

Figure 24. Relation of Temperature to Life. (From Pearse.)

inquiry, viz., those of "cooling," "shrinking," "atomic decay," "erosion," "concentration," and "organic evolution." Although the forces producing change always work in combination, each of

these may be separately thought of and discussed. One of the characteristic progressive processes or activities is that of cooling. The hot core of the earth is not far down. Within a hundred

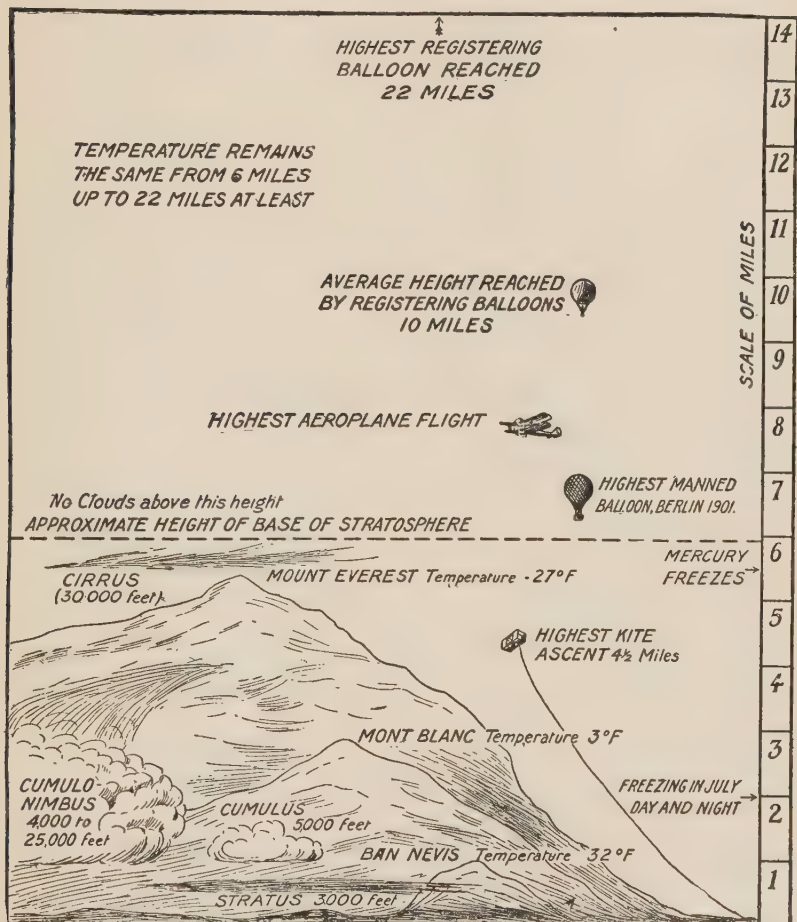


Figure 25. Exploring the Atmosphere. (From Thomson.)

feet of the surface of the earth the diurnal and annual variations due to the sun's heat fade out, and we get a temperature which is practically invariable—a temperature less than  $5^{\circ}$  above the average temperature of the surface.

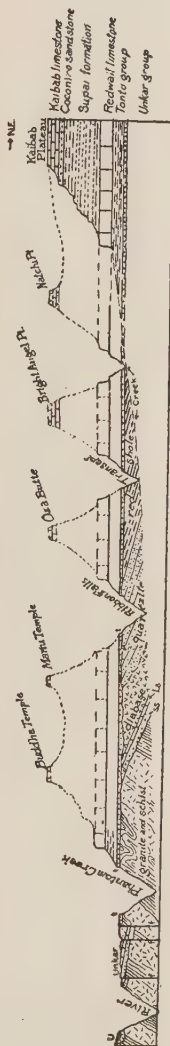
**Cooling—Its Relation to Structure.** Below this level, the deeper we go the hotter it gets and the temperature of the earth increases in orderly fashion. The pressure increases. Two actions, expansion due to heat and contraction due to gravitation, work in opposite directions, so far as their effect on volume is concerned, and tend to counterbalance each other. Do they, in fact, operate in exact balance? Are these forces really sta-



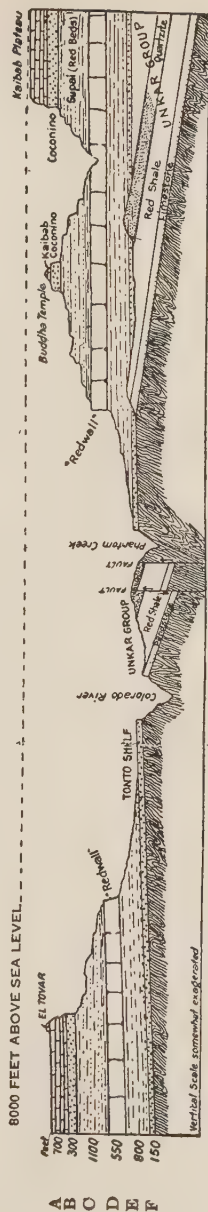
Figure 26. Detail of Erosion in the Grand Canyon. The inequalities of slope are the result of unequal hardness. The vertical planes which give the architectural effects are the result of joints. (From Chamberlin and Salisbury.)

bilized? These are among the questions the student of geology has to solve.

One of the elements of the problem is consideration of the weight of the earth-mass as a whole compared with that of the surface rocks. As bearing on this problem many measurements and calculations have been made. The conclusion commonly accepted is this: that the surface rocks weigh about 2.8 times as much as an equal volume of water; whereas the weight of the earth as a whole is just about twice as great (5.52). The estimated



SECTION ALONG BRIGHT ANGEL CREEK  
SS, Sandstone; LS, Limestone of Unkar Group, U. F. Fault; T, Basal Sandstone Tonto Group



SECTION ACROSS GRAND CANYON WEST OF BRIGHT ANGEL CREEK FROM EL TOVAR TO KAIBAB PLATEAU

- |   |                                  |   |                             |
|---|----------------------------------|---|-----------------------------|
| A | Kaibab Limestone                 | D | Redwall Limestone           |
| B | Coconino Sandstone               | E | { Shales } Tonto            |
| C | Supai (Red Sandstone) and Shales | F | { Sandstone } Granite, etc. |

Figure 27. Cross-sections in the Grand Canyon

difference in weight has been attributed by some to the condensing effect of pressure.

But Bridgman's experiments indicate that there are limits to the condensing effects of pressure; and there is another factor of importance, namely, the change in composition with increasing depth. The meteorites which come in from space are largely native iron. The igneous rocks, that seem to have come from a hotter and deeper source, contain more iron than does the granite crust. The earth as a whole is magnetic. For these reasons it is generally believed that the core of the earth is largely iron. Thus we have an orderly arrangement of the materials of the earth (air, water, rock, iron) as well as of the temperature and pressure.

**Shrinking—Its Effect on the Spin of the Earth.** Now the pressure is relatively invariable with time, but the loss of energy from the interior is progressive and always goes on. Heat tends to expand the mass. Loss of heat causes the mass to shrink. Because of the loss of energy, there must be a tendency to shrink the size of the earth. An interesting conclusion follows. This shrinking of the size would tend to make the planet spin faster—as every boy knows who has shortened a sling in his hand. In a recent controversy between Reid and Chamberlin on the latter's planetesimal hypothesis, Reid pointed out and Chamberlin agreed that the velocity of the spin of the earth (the moment of momentum) could be accounted for only by a very considerable shrinkage, and not by a simple aggregation of a lot of smaller bodies (planetesimals).

On the other hand, while shrinkage would tend to make the earth spin faster, the energy of the tide-mills is derived from the energy of the spin of the earth, and the general effect of the tides is to retard the rotation of the earth. Estimates of this progressive action were carried back by G. H. Darwin (without allowing for shrinkage) to a time when the earth and moon were nearly in contact—when the latter, perhaps, was thrown off from the earth by the rapidity of rotation; and they were carried forward to a time when the month and the day would be of the same length.

Shrinkage due to pressure means a tremendous conversion of

energy into heat, enough to account for any initial temperature of which we have signs; but the development of heat by pressure would tend to retard the shrinkage. Thus, while shrinkage is working always one way, it is quite likely that the rate of shrinkage of the earth varies, and may be growing progressively less. At any rate the balance between the forces that tend to retard and those that tend to hasten the rotation of the earth is so close that the net retardation is not more than a few seconds in each century; and Professor E. W. Brown of Yale holds that the retardation is periodic rather than progressive.

**Atomic Decay and Radioactivity.** Another progressive activity is that of the decay of atoms—from which radium gets its curious and valuable properties. Luminous paint is frequently made from a radium salt to which phosphorescent zinc sulphide has been added. If with a good pocket lens we look at a surface on which such a paint is used, containing radium or thorium, after sitting for a few minutes in darkness, we shall see sparks like glowworms. Each of these sparks represents the explosion of an atom in the radioactive substance, in which an atom of helium is sent flying off with such force that it strikes the zinc sulphide like a bomb and makes it glow. There is left a residue of another element. Uranium is the grandparent of radium and, so far as we now know, lead is the final residue, though on the way the matter is transformed into radium and more than a dozen other elements.

From the proportion of lead to uranium and thorium we may infer a limit to the age which a mineral or rock can have, just as we might tell from the proportion of popped to unpopped corn how long a corn popping machine had been running if we knew how fast it was popping. Yet in all these progressive activities, we have to look to a beginning either arbitrarily assumed, or produced by some other process. As yet we know little about how or when uranium came to be. So far as we know, these changes have taken place on a one-way street—i.e., the changes from uranium to and through the substances described have gone on regardless of temperature or pressure under conditions such as may be assumed to have existed near the surface of the earth. Very recently C. W. Davis analyzed a mineral from the Black

Hills of Dakota whose lead, by its atomic weight, shows that it is derived from the radioactive elements. Its proportion of these elements (22 per cent) indicates that the mineral began forming 1,518,000,000 years ago. If we continue to carry this process back, we find that if it had started twice as long ago the proportions of uranium, thorium, and lead in the crust and the atomic weight of average lead could not be what they are, as H. N. Russell has pointed out. This illustrates the fact that all such processes point to a beginning.

**Concentration and Chemical Disintegration.** Another progressive process is that of "concentration" of the various elements and minerals contained in rocks. This goes along with the process of disintegration and separation of the constituent elements and minerals. A rock decays. The sodium and more soluble parts find their way into the ocean—there to remain until the sodium is laid down in beds of rock salt. The lime first deposited in the fabric of plants and animals, finds its way into beds of limestone. The carbon dioxide is seized by plants; the carbon may be laid down as beds of coal, and the oxygen and nitrogen may partly accumulate in the air. The hard and resistant quartz of the granite accumulates by itself in beds of sand and sandstone. Other materials pass into clay.

As usual, progress is the resultant of contending actions. Plants tend to absorb carbon dioxide; but animals tend to eat the plants which give out oxygen that may recombine with the carbon laid down by the plants; man especially is turning coal back into carbon dioxide on a large scale. Nevertheless, it is not unlikely that the old proverb "Birds of a feather flock together" is finding a progressive fulfillment—that "concentration" is going on all the time.

**Evolution—Organisms as Mechanisms of Progressive Change.** Another progressive process is the evolution of life. If living organisms were subject to no other environmental forces than is the molecule or the crystal, there would be a recurrence of similar forms of life. But organisms are not like the silica which crystallizes into quartz of identically the same form as a thousand million years ago.

An essential feature of life is the specific type of chemical or

physical mechanism through which the energies called “vital” work. The life mechanism of a given species may be likened to the sails of a boat which the mariner may set so as to beat against the wind that is its environment. It is not our purpose to go farther into the biological field than to point at two facts: (1) that the mechanism in which and through which energy expresses itself as “life” is one that in form and “species” changes; and (2) that the progression of changes in each hereditary line does not run exactly as in an orbit, any more than do other progressive changes recorded in earth structure. Geological research confirms this conclusion. So far back in time as the records of fossils run, there is no evidence that a form which has once died out has ever reappeared.

**Difference Between Periodic and Progressive Changes.** All progressive processes point to a differing goal for each process—one which has not been reached—one, indeed, which in each persisting process it might take an infinite time to reach. Knowledge of progressive changes also implies a beginning; for all progressive processes this must be presumed. Herein progressive processes differ, as we have seen, from the periodic processes. Were the processes of nature all periodic we might then say with the early school of geologists called Uniformitarians: “In the economy of nature there is no sign of a beginning, no prospect of an end.” This is certainly not true of the progressive processes.

**Paroxysmal Processes.** Paroxysms are events not predictable by inference from what goes before. They are neither periodic nor progressive. This does not mean they are without cause. It means that the effect of paroxysms or sudden breaks is not proportional to the force that is the immediate cause (the usually assigned cause) which fixes their occurrences. They are equivalent to the last straw which is said to break the camel’s back. But the terminal result is not proportionate to the weight of the last straw. In everyday experience an explosion, the boiling or freezing point in chemistry, the crushing point in mechanics, marks paroxysmal occurrences. A collision such as brings out a nova (a new flare of brightness) among the stars is a paroxysm in the heavens. Earthquakes, volcanic outbursts, landslides, are

illustrations of what is meant by paroxysmal processes affecting the surface of the earth.

A strain accumulates in the earth's crust. Sometimes the crust yields gradually; but often it cracks and such a crack produces an earthquake. Up along the crack may rush molten rock or gases from the interior and, if they reach the surface, we have a volcano. Or there may be hot waters bearing a precious burden of the heavier metals, which they deposit in the fissure veins.

**Combinations of Forces: Periodic, Progressive, and Paroxysmal.** Now may be noted a possible effect of combining "progressive" with "paroxysmal" activities. If the latter comes at regular intervals, a periodic activity, or cycle, results. For instance, the loss of energy from the interior of the earth leads to strain. If this strain can accumulate and if, whenever it reaches a certain amount, a collapse takes place, we have something like a periodic process regularly occurring—as in the case of a geyser. Something of this sort in a very large way seems really to have happened, as nearly as we can read the records of the rocks. At the time of collapse the surface is roughened; internal forces play the leading rôle; mountains are uplifted, and there are corresponding depressions in the bottom of the sea. Thus the continents are enlarged; the larger a continent is the more extreme the climate. And at such times of enlargement, we may have left in some places signs of glaciers and their deposits; in other places, also, we may have left desert deposits, wind blown sands and perhaps salt; volcanic rocks may be ejected to the surface; their injected igneous equivalent may be elsewhere exposed in the cores of the mountain ranges. Then when the strain has been relieved, the forces of degradation, continually at work, once more become conspicuous; and the tide of battle in the great struggle between the forces of elevation and degradation once more will swing the other way.

Of course, these swings are not as regular as the spoutings of "Old Faithful" in Yellowstone Park. But on the whole, such a combination of paroxysmal and periodic action brings about a stepwise progress. The exact order of this progress depends upon a combination of forces: periodic, paroxysmal, and progressive.

Just how the strain accumulates to produce a paroxysm is not yet clear—for the outer rind of the earth is only some thirty-six miles or less thick, and cannot accumulate much strain. Furthermore, it rests on a layer that cannot remain at rest in a state of strain. Thus, the continents remain above the ocean, not because the rind can sustain them, but because the rocks beneath the ocean are heavier than the rocks beneath the continents—so that as a matter of adjustment, continents project like floating logs. It has even been suggested not only that they float but that the old world is slowly creeping away from the new. No less an authority than Termier, the head of the French Geological Survey, has suggested that the story of the lost Atlantis is really founded on fact.

### QUESTIONNAIRE WITH READING REFERENCES

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#### 4. What is included in cosmic or "astronomical" geology; how is this distinguished from "terrestrial" geology?

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#### 5. What are the main subdivisions of terrestrial geology?

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#### 6. What are the several concentric "spheres" with which the geologist deals?

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12. What are some of the leading special sciences included in the dynamic aspect of geology?

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 Cleland, *op. cit.*, p. 21.

13. What are some of the related sciences dealing with the practical aspects of both the static and dynamic phenomena of the earth?

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H. Ries, *Economic Geology of the United States* [N. Y.: Macmillan, 1905], (See chapter outline and bibliography).

14. What are some of the specialized subjects of research which depend on the interrelations of the physical sciences—such as the relations of mathematics, chemistry, physics and biology to terrestrial structure and phenomena?

15. In what sense may we think of the earth as a stage on which the drama of life is played? Discuss in terms of essentials to dramatic setting, motive and action.

A. C. Lane, in *Sci. Monthly*, Nov., 1915, p. 132.

A. Holmes, *The Age of the Earth* [N. Y.: Harper, 1927], Ch. V, Rhythms and revolutions in the earth's history, pp. 45-53.

16. Using this figure (life as a play and the earth as a stage) what are the forces in conflict in the continuing drama that is being enacted thereon?

17. As related to the results of conflict between forces external and internal, in most general terms how are these forces characterized? What is meant by the phrase "the forces of elevation"?

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19. What is meant by the phrase "the forces of degradation"? What forces of degradation tend to level the surface of the earth and why is the earth's surface not level?

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34. What are the chief classes of dynamic terrestrial phenomena taken into account by geologists?

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35. How are the progressive changes to be distinguished from the paroxysmal?

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36. What are the several progressive processes in the earth's history?

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37. What is the relation of "cooling" to earth structure?  
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38. What is the effect of shrinking in the spin of the earth and what tends to off-set this effect?  
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39. How are the tides accounted for and what is thought to be their effect on the spinning motion of the earth?  
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Hevesy and Paneth, *op. cit.*, The hypothesis of atomic disintegration, pp. 3-5.
41. What application is made of this factor of progressive change to the geological theory of cosmic evolution?
42. Discuss the process of concentration and chemical disintegration as applied to the formation of rock-salt, limestone, coal, sand and sandstone.
43. In what respect does organic evolution differ from the formation of molecules and crystals?
44. How are progressive changes to be distinguished from those which are periodic?
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## CHAPTER VIII

### HISTORY AS WRITTEN IN EARTH STRUCTURE \*

**Geology as a Study of Strata.** In the pages immediately preceding we have been dealing with the dynamic forces which have operated to change the earth's structure. We come now to that aspect of geology called "static"—the observed facts that find systematic arrangement in that specialized branch of the subject known as "stratigraphy." A very interesting conception of earth structure is found in the presidential address of Sir John Murray before the geological section of the British Association in 1899: "When we regard our globe with the mind's eye, it appears at the present time to be formed of concentric spheres, very like, and still very unlike, the successive coats of an onion. Within is situated a vast nucleus or *centrosphere*; surrounding this is what may be called the *tekosphere* <sup>1</sup> (tekos, molten), a shell of materials in a state bordering on fusion upon which rests and creeps the *lithosphere* (lithos, rock). Then follow *hydrosphere* (hydro, water) and *atmosphere*, with the included *biosphere* (bios, life). To the interaction of these six geospheres, through energy derived from internal and external sources, may be attributed all the existing superficial phenomena of the planet." Seismology (the study of earthquake waves which, like the light waves that enable us to see the interior of a glass marble, are enabling us to see through the earth) has given us a different conception of the probable condition at the earth's core. But whatever exception may be taken to the above very broad and general portrayal of terrestrial order, it suggests the subject matter both of dynamic and static geology.

**The Earlier Classification of Strata.** Concerning that part of the earth's crust that has lent itself to direct scientific observation there is little difference of opinion. A great body of concrete

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\* By Professor Alfred C. Lane (see note at beginning of Chapter VII).

<sup>1</sup> This, Barrell of Yale called the asthenosphere, weak layer, and seismology shows at least two divisions in the centrosphere, the inner probably iron.

information has been collected by geologists about the relative position and age of stratified rocks. However, these facts and findings from time to time have been differently classified. By earlier observers, the various superimposed layers which make up the "lithosphere" were classified as "primary," "secondary," "tertiary," and "quaternary" formations. The "primary" rocks were those which, in earlier treatises, were thought of as "igneous"

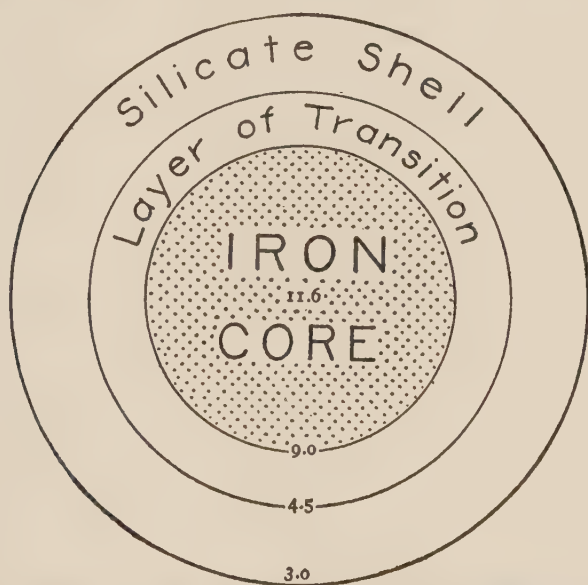


Figure 28. Section through the Earth's Center, showing the Iron Core, the Layer of Transition, and the Silicate Shell, with densities of each. (From Daly.)

(fire) formation. The igneous rocks were assumed to make up the oldest formation. They were the floor, so to speak, of the first seas, in which surface washings were deposited. As age succeeded age, conditions changed; and the deposits were supposed to have a different character. Because of this fact, each age group of sedimentary rocks was supposed to be recognizable—wherever they might be discovered—whatever might be their geographic location. Thus, wherever the same kind of rocks was identified by one observer or another, it was assumed to represent the same geological period.

**Latter-Day Classification.** But early in the development of the science it became apparent that the assumption above noted was not true. Only when sufficient fossil remains were found could the character of the rocks be positively identified with a period. In other words, the findings of the paleontologist (in his study of what Sir John Murray called the "biosphere") came to be essential in the determination of the age to which the several kinds of sedimentary rocks of the "lithosphere" belonged. The division of the earliest rocks in which no well-marked fossil remains have been found is still much disputed. It is the hope of the geologist that they may ultimately be dated by the amount of atomic decay that may have taken place in the radium-bearing minerals they contain. After the fossil (the subject matter of paleontology) came to be accepted as the common basis for organizing materials collected to determine the relative ages of rocks, the first general arrangement was in four eras: (1) the Eozoic or dawn of life; (2) the Paleozoic—rocks containing the remains of the oldest, well-defined types of life; (3) the Mesozoic or age of reptiles—rocks containing the remains of more advanced species, occupying a middle place in the evolution; (4) the Cenozoic—rocks containing the remains of species evolved in a more recent period. This older, broad, four-era biological classification, however, soon came to be broken up into systems.

**The Cambrian and the Precambrian Rocks.** Among the outstanding geologists of the early part of the last century was an Englishman named A. Sedgwick, who spent much time studying the outjutting strata in the Welsh (or Cambrian) hills. His findings were carefully classified; and all the sedimentary rocks containing fossils similar to those found in this region came to be known as the Cambrian system. The highest fossils were trilobites like the horseshoe crab. Beneath the strata in which they were found were other rocks which, for many years, were thought to contain no fossils. Afterward, however, in these lower lying strata were found (besides indirect evidences such as limestone) the casts of the fossil remains of primitive species. Therefore, to these sub-strata the geological name of "Precambrian" or Eozoic or Proterozoic has been given. In these the signs of life are few or difficult to find, but there are many evidences of

volcanic action. The Cambrian strata were distinguishable because of the shell casts of trilobites, etc.

**Ordovician and Silurian.** A contemporary of Sedgwick, Sir R. I. Murchison, in 1835 made known the results of his study of rocks on the border of England and Wales. He carried his study further and included studies of rocks which not only contained the fossil remains of the primitive species described by Sedgwick, but also of rocks somewhat more advanced. Murchison gave to the strata described by him the name "Silurian System" from an old Welsh tribe. Because the two systems overlapped, an ardent controversy arose over questions of classification. This continued for a half-century. Finally, a basis of classification was proposed by Professor Lapworth. He suggested that the way out was to set up three general groups; and he gave to the first (the oldest) the name Cambrian; to the second or intermediate the name Ordovician (from an old British tribe living in North Wales); and reserved for the third the name used by Murchison, viz., Silurian. Between the Cambrian and the Ordovician there is evidence of only mild disturbance in America. But the fossils are quite different. The Cambrian forms were thin shelled. This is not so true in the Ordovician and remains of many new kinds of animals and plants appear in abundance—in fact all branches of the tree of life except perhaps the vertebrates. There are some remnants that suggest fish. But if these are fossils of fishlike animals, they had no hard backbones.

**The Devonian and Carboniferous Systems.** Then followed what has come to be called the age of fishes—the Devonian—named from Devonshire. This is the system of rocks in which fish with hard parts, largely external armor, first abound. Through the long, long ages while the Cambrian, the Ordovician, and Silurian strata were being gradually formed by the slow process of wearing down the surface of continents and washing the sand and silt into the seas by disintegration, the soluble salts of the chemically changed rocks of all kinds were separated out. The sea accumulated more salts. Sea-species were evolved with hard, thick, protective shells—and mobile animals (sea and land) were evolved with hard bony structures. Presumably because of climatic and other changes, land plants increased and became

more highly developed. And overlying the Devonian system is a group of rocks prolific in plant life that gets its name from the coal veins and other fuel deposits—rocks of the Carboniferous age. The period in which these strata were formed must have been one in which conditions favored a luxuriant growth of ferns, mosses and other vegetation that thrive in a moist atmosphere.

**The Permian System.** Last of the long series of strata that were formed during the Paleozoic era is the system of rocks called Permian. This name came from the province of Perm, in Russia, where Murchison and his coadjutors in geological reconnaissance went in 1841, to study a series of strata immediately overlying the Carboniferous. As distinguished from the Carboniferous age, this was a period of glaciation and volcanic disturbances, of widespread land masses and of continental climates involving deserts and salt deposits in some places, as in the great German Strassfurt deposits, while in other places were glaciers, and in still others, forests that formed coal. Whether the volcanic disturbance was caused by the changing pressure due to glacial formations, or whether the accumulations of ice were effect instead of cause, need not be discussed here; the fact to be noted is that this was a period when many folds and cracks and intrusions of granite occurred—such as found in Quincy, Massachusetts, and other places in New England. And similar disturbances took place in England, France, and Germany. With this was a change in biological types—more signs of land animals.

**The Mesozoic Era.** For the purposes of this brief discussion of stratigraphic arrangement, we refer back to the broader biological divisions. Leaving the Paleozoic, we come now to what is called the “middle” biological era, the Mesozoic. This includes three well-established and recognized systems of rocks—in order of their formation, called Triassic, Jurassic and Cretaceous. The word Triassic is derived from a root word indicating the triple division which could be easily made out in the rocks of the system in Germany where the name was first used; the word Jurassic comes from the Jura Mountains between France and Switzerland; the name Cretaceous is derived from a root word meaning chalk or chalky.

The Mesozoic era is sometimes popularly called the “Age of

Reptiles." It is a fact that a period of "elevation" with its characteristic climate and other changes always means biological development, with the introduction of new life forms. During the Carboniferous period there were few and relatively small reptiles; in the Mesozoic there was a great variety of reptilian life—both carnivorous (with cutting teeth) and herbivorous (of the duck-billed species); there were flying dragons and sea serpents—some huge, some small, some adapted to a hot, dry climate, and some to a wet climate; but none of the reptiles were adapted to a cold climate and that may account for the fact that they were finally displaced with the oncoming of the subsequent ice age, the second glacial period.

The three systems of rocks included in the Mesozoic era (Triassic, Jurassic and Cretaceous) are separated from each other by lesser mountain-building disturbances and uplifts. On the whole, however, the forces of degradation became more and more dominant—until during the later Cretaceous times the land was widely reduced to a nearly level, featureless plain about which rose a few rounded hills—known as monadnocks, after Mount Monadnock, New Hampshire. This plain, more or less overlapped by a sea, or by characteristic chalky deposits, subsequently uplifted or disturbed by internal and lateral pressures, is known as the Cretaceous peneplain.

During all this time mammals (warm-blooded animals that suckle their young) existed—although they made little progress, and developed no further than such species as are now typified in the kangaroo rats. In the Cretaceous period, however, we do find marked progress in the plant forms, and here in abundance are fossils of the flower, the nut- and the fruit-bearing herbs, shrubs, and trees. At the end of the Cretaceous, the last of the Mesozoic era, another great disturbance occurred. The waters which had extended so far over the shallow ocean floor withdrew, the climate became colder—and with this atmospheric cooling there was less aridity and more rain. This change may have helped to diminish reptile life. Coolness in climate was favorable to the further development of the warm-blooded species; it also favored the development of species with protective coatings of hair, fur, etc., to keep them warm. At the same time, it is possible that these warm-blooded animals learned to suck reptile's

eggs and so were instrumental in the downfall of the large cold-blooded land species. Beside hair, warm blood and the consequent capacity for sustained activity, the mammals had another advantage over reptiles in the longer association of parent with child—from which sprang the family and unselfishness. This, however, introduces a subject that is enlarged upon by other writers in later chapters.

**The Cenozoic Era—Neozoic or Tertiary.** The age of mammals since the Mesozoic era has received various names—the name “Cenozoic” being as recent as any. The names of the several divisions of the Cenozoic era have a common characteristic ending in “-cene.” Thus the rocks are successively arranged and we have the names Paleocene (or the oldest of the included periods); Eocene; Oligocene; Miocene; Pliocene; Pleistocene. It was during this period that the highest existing mountains were uplifted—the Andes, the Cordilleras, the Himalayas, the Alps. Some of them are probably still growing. Such recent earthquakes as those of San Diego and Japan indicate their growing pains. Earlier formed mountains had been worn down almost to a level—such mountains as the Appalachians owe their height little to the original folding but mainly to a recent bodily uplift.

**The Age of the Mammals.** During the uplift disturbance at the beginning of the Cenozoic era, the mammals developed so rapidly that the steps of change are as yet unfound. For the rest of the Cenozoic era, however, the changes—following the law of adaptation—have been so gradual that in many cases we can follow each stage in its adaptation to special habits of life. For instance, the horse changed from a small brush-eating animal to a fleet grass-eater of the plains; its legs lengthened; and from running on its toes, it got to running on a highly changed toe that became a hoof; its teeth also lengthened to stand the wear of eating grimy grass. Similar development made a wing out of the five-fingered hand of the bat—and turned the hand of the warm-blooded swimming animals, the seal and the whale, into a flipper; and one of these to protect his warm blood while in frigid waters came to bear a coat of fur, while the other came to wear a thick undercoat of blubber. There is an orderly progress in accord-

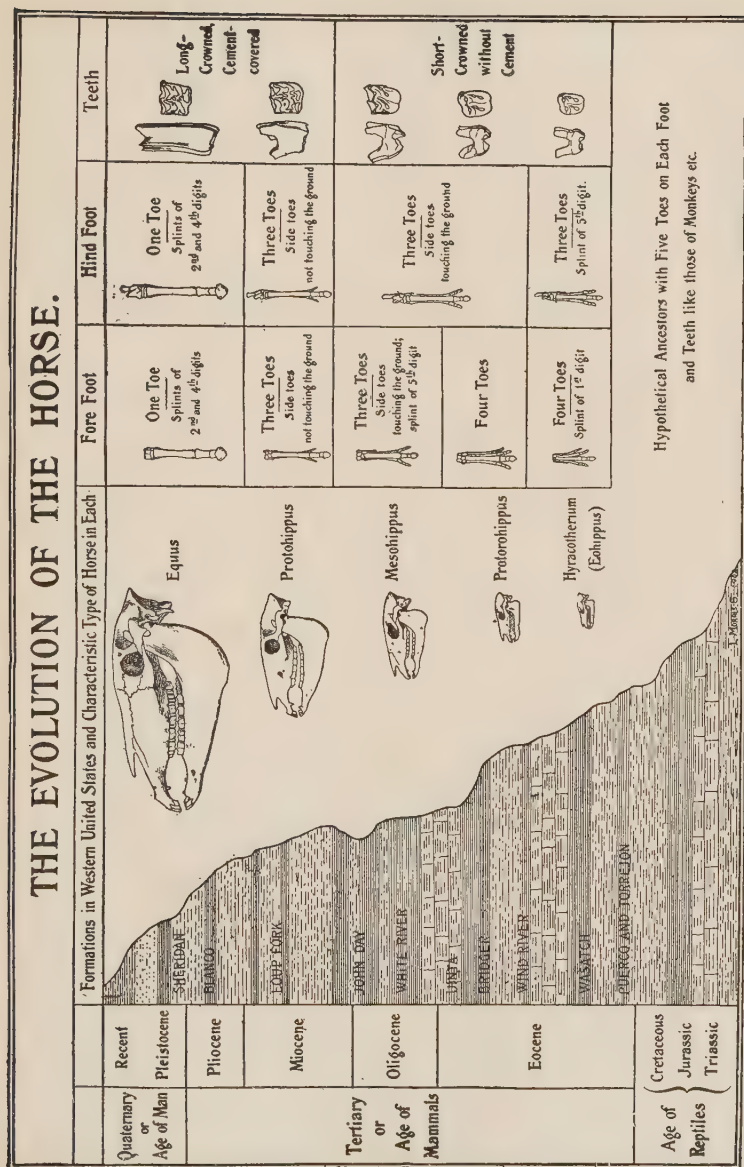


Figure 29. Evolution of the Horse. (Courtesy of the American Museum of Natural History.)

ance with the fundamental principle that each new organic adaptation spreads as far as it can relate itself to various uses—just as we have seen the automobile develop into trucks, racers, buses, and flivvers.

The variety of changes is indicated by evidences, left to us in the rocks of the Cenozoic, of a fairly dry and mild climate in the Miocene period; of further uplift (in the Pliocene) ushering in an epoch of glaciation that reaches its characteristic development in the Pleistocene. It is from this period that we are now emerging. Greenland and Antarctica are still swathed in ice—just as a considerable part of Europe and America were a few thousand years ago.

From these facts, too hasty conclusions must not be drawn. It must not be supposed that there was a great advance of the ice sheet and then a steady recession. Ice began to gather and glaciers carved such glacial amphitheaters as Tuckerman's Ravine and Great Gulf in the White Mountains of New England. It retired and readvanced. It shifted the center of accumulation from west of Hudson Bay to east. Its farthest limits in America were reached when it extended as far as Long Island (leaving this landmark as its terminal moraine on the Atlantic shore), and in the Middle States as far as Kentucky. In Europe the Scandinavian glaciers crossed the Baltic and the North Sea—carrying rocks from the mountain ranges that separate the Baltic and North Seas south and west and leaving them as boulders in Germany and England. The Alpine glaciers extended down the valley of the Rhône to the sea. At the same time there was a "pluvial" period in Palestine and probably large lakes in Nevada and Utah. The great ice sheets weighed down the crust beneath them and as these retired, great lakes were impounded; and these shifted their size and shape as new outlets opened with the retreat of the ice; progress and retreat are alike stepwise.

**The Psychozoic Era.** To the four names of great groups of rocks classified according to the fossil remains of biological species (Proterozoic or Eozoic, Paleozoic, Mesozoic, and Cenozoic), a fifth has been added—a name given to the most recent groups in the Cenozoic. These have been taken as ushering in a new era called the Psychozoic. The significance of this word is

that it has reference to the appearance of man on earth. More directly this focuses attention on that part of the earth's superficial structure in which is found the fossil remains of human forms. By way of historic approach it is to be observed that among animals of the Mesozoic era, the monkey tribes did not develop high physical specialization. Their feet were not adapted to swift motion, nor did they turn their wings into flippers or claws. Their teeth were not especially adapted for gnawing nuts, for tearing flesh, or for eating grass. Among so many specializing animals, the specialization of the early primates may have been in using their wits to gain food and protect themselves from harm in a variety of conditions. They came to be omnivorous—ate anything that could sustain life. In the exercise of their wits they became curious, inquisitive—qualities of mind characteristic of monkeys and scientists. Some, but not all of them, for self-protection and food-getting, so took to the trees that their tails became specialized as means of holding on. All of them apparently developed the art of taking hold of things, and with this art came to have a hand with a thumb. Perhaps because they lacked the inherited protective equipment of carnivora and other animal neighbors, some of them learned to throw stones—and perhaps some learned that a stone broken with a sharp edge was more effective; flint implements were developed to take the place of teeth, beak, and claws. They may have learned that fire protected them from other animals, from the cold as well, where needed, and that it could be used for cooking. As the cold of the glacial period increased, instead of disappearing as did many of the reptiles, or migrating or awaiting the slow evolutionary process of growing fur of their own, they may have learned to take the skins of other animals and to wear these as clothing.

**The Age of Man.** Here, as the geological remains give evidence, is the beginning of an age of conscious striving after adaptation in the invention of means to end; and with consciousness of mental states, invention was finally expanded to the means of indicating to each other states of consciousness—giving rise to pictures, language, and other expressive arts. In these latest strata (largely alluvial) are evidences of what has come to be known as culture and civilization—burial rites and altars, with

their associated cosmological and other conceptions which show that man came to have religious as well as other sentiments by which individuals and groups were guided and became cooperative. It is natural that as man became self-conscious and realized that he himself caused things to happen for preconceived ends, he should infer that the world about him was similarly governed and that he should come to organize around this notion of Creator and Omnipotence a sentiment of religion and devotion. That part of the earth's crust which bears evidences of increasing funds of knowledge acquired by individuals of the human species after birth and the culture passing down from generation to generation, finally came to be the subject of specialized scientific inquiry. For historic as well as scientific perspective and interpretation in this field we now look to the fast-growing literatures of anthropology, mythology, religion, and comparative psychology.

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H. F. Cleland, *Geology, Physical and Historical* [N. Y.: American Book Co., 1916], Ch. XIII, Historical geology, pp. 377-384.

2. What was the basis of classification of strata employed by the earlier observers?

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9. What are the characteristics of the Ordovician and Silurian systems and how do these derive their names?  
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 Shimer, *op. cit.*, pp. 198-206.  
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 Pirsson and Schuchert, *op. cit.*, Pt. II, Ch. XXXVIII, Devonian time and the dominance of fishes, pp. 695-713; Ch. XL, Carboniferous of older geologists and the Mississippian period, pp. 728-740.
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Shimer, *op. cit.*, Ch. XV, Cenozoic, pp. 238-272.  
 Miller, *Introduction to Historical Geology*, Ch. XVIII, Tertiary period, pp. 281-327; Ch. XIX, Quaternary period, pp. 328-382.  
 Chamberlin and Salisbury, *op. cit.*, Vol. III, Ch. XVI, Eocene period, pp. 191-257; Ch. XVII, Miocene period, pp. 258-295.  
 Pirsson and Schuchert, *op. cit.*, Pt. II, Ch. LII, The dawn of the recent in Cenozoic time, pp. 910-926.

14. What is the meaning of the suffix "cene" as applied to the several systems of rocks included in the Cenozoic era—Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene?

Miller, *Introduction to Historical Geology*, pp. 281-282.  
 Pirsson and Schuchert, *op. cit.*, Pt. II, pp. 910-911.

15. What are some of the best known examples of variation and evolution of species recorded in the rocks belonging to the Cenozoic era?

Miller, *Introduction to Historical Geology*, Ch. XVIII, The Tertiary period, pp. 281-327; Ch. XIX, Quaternary period, pp. 328-382.  
 Shimer, *op. cit.*, Ch. XV, Cenozoic, pp. 238-272.  
 Chamberlin and Salisbury, *op. cit.*, Vol. III, Ch. XVI, Eocene period, pp. 191-257; Ch. XVII, Miocene period, pp. 258-295.

16. What is characteristic of the Pliocene and Pleistocene periods?

Miller, *Introduction to Historical Geology*, pp. 286, 289-290, 328-364.  
 Chamberlin and Salisbury, *op. cit.*, Vol. III, Ch. XVIII, Pliocene period, pp. 296-326; Ch. XIX, Pleistocene or glacial period, pp. 327-516.  
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17. How are the great glacial periods accounted for?

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 H. Jeffreys, *The Earth* [Cambridge, England: Univ. Press, 1924], App. D, Theories of Climatic Variation, pp. 262-267.  
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18. What are some of the well-marked evidences and remains of glacial action in North America?

Wright, *Ice Age in North America*, Ch. VII, Boundary of the glaciated area in North America, pp. 134-193.  
 Miller, *Introduction to Historical Geology*, pp. 328-356.  
 Chamberlin and Salisbury, *op. cit.*, Vol. III, pp. 330-337, 379-413.

19. In what strata or systems are the fossils of the following living things first found to be abundant: mosses and ferns, flowers, trilobites, coral, fish, insects, reptiles, birds, mammals?

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 Shimer, *op. cit.*, p. 173; Ch. XX, Summary of plant and animal life, pp. 380-392.

Schuchert, in *Evolution of the Earth*, p. 46.

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21. What is the significance of the term Psychozoic era?

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22. Why is the present called "the age of man"?

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## CHAPTER IX

### ORDER AS SEEN BY THE PHYSICIST \*

#### The Older Physics <sup>1</sup>

**The Physicist's Field of Inquiry.** The physicist deals with certain laws of Inanimate Nature—that is, with the ways in which Nature acts in the realm of the inanimate world. The physicist deals with energy and the motion of bodies under force. So, indeed, does the astronomer, but his particular field covers stellar universes. So does the chemist, but he deals especially with the interaction of atoms and molecules. The geologist studies mainly our earth, the meteorologist Inanimate Nature in clouds and storms, in winds, and the weather.

The reader will conclude—and rightly—that the boundaries between the domains of all the branches of the great Science of the Inanimate are vague and ill-defined. In a sense each scientist is at work in the same field—Science. Each group of scientists studying the laws of Inanimate Nature adds to the sum total of human knowledge. Each helps to broaden perspective. It is thus that mankind gradually becomes aware of certainties upon which he can rely when dealing with his environment and planning for his present and future needs.

**Reasons for Distinguishing the Old Physics from the New.** During the last three decades, physical experimentation has led to conclusions which are revolutionary. This does not mean

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<sup>1</sup> The writer wishes to acknowledge his indebtedness to Dr. Edwin C. Kemble of Harvard for reading the manuscript of these chapters and for his numerous and valuable suggestions, more particularly the sequence of the subjects covered in the summary near the end of Chapter X.

that centuries of work and the observations of many workers have been lost or set aside by new discoveries. These former labors still serve as the foundation upon which the newer physics has been reared. The older physics is before us; a discussion of the newer physics follows in Chapter X. It is important that the two be dealt with separately (1) because the subject matter is quite different, and (2) because in the newer physics we are dealing with conclusions which have widened enormously the horizon of astronomy, geology, chemistry and other related sciences.

**Subject Matter and Nomenclature.** The older physics includes the domains of mechanics, sound, heat, magnetism, electricity, and light. Upon these subdivisions of the sciences we shall briefly touch. Before doing so, however, it seems desirable to state what the physicist means by certain words which in everyday life are used rather loosely, viz., force, pressure, work, energy, and power.

The physicist means by the term "force" that something which tends to change the rate at which a body is moving, and by "pressure" the force divided by the area over which it is exerted. By "work" he means the product of the force by the distance through which a body is moved in the direction of the force and by "energy" the ability a body possesses to do work. "Power" is the work divided by the time which elapses while the work is being done.

### Mechanics

**The Science of Machines.** Man's achievements in the field of mechanics are the direct result of the discovery and application of very simple laws dealing with the combining of forces so as to produce motion or lack of motion in a mechanical system or any of its related parts; and the ultimate simplicity of all mechanisms is well illustrated by the fact that there are but two simple machines—the lever and the inclined plane. Upon the basic principles of these are constructed all our mechanical devices, from such tools as the simple hammer and screwdriver to complicated mechanisms such as the clock, the automobile, the modern industrial plant or transportation system. This is but an example of the general principle that the *discovery of Nature's laws or the*

*ways in which Nature "acts," is the basis of all invention—the key to human material progress.*

**Molecular Forces.** Molecular forces manifest themselves to us in the events of everyday life. For instance, a dry sponge will not "soak up" water, nor will a starched towel. The bicycle rider, venturing out on a muddy day with no mudguards, is sprinkled with muddy water thrown upon him by the wheels. The

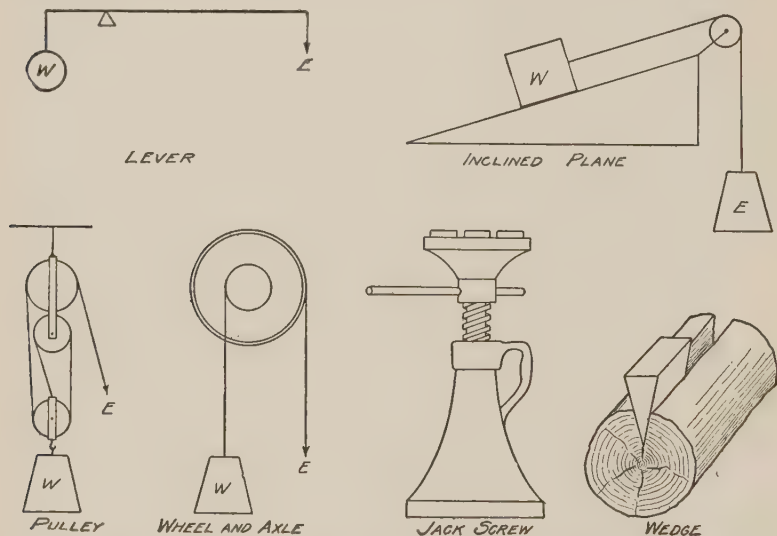


Figure 30. Simple Machines—The Lever and Inclined Plane. The pulley and wheel and axle are variations of the lever; the jackscrew and wedge are variations of the inclined plane. *W* represents a weight and *E* a force applied as effort.

camper knows that during a rain, he must not touch the under surface of the canvas above his head, else his tent will thereafter leak at that point until dried out again. Physics tells us that these simple facts are merely manifestations of the molecular forces of cohesion and adhesion.

**Forces and Molar Masses of Matter.** The physicist deals also with forces applied to larger portions of matter and many devices of great practical service to man are due to his researches. To him we are indebted for the use of the pendulum in our clocks and the hair-spring in our watches. Following the principle that

"nature abhors a vacuum," Pascal showed that this is so because the air has weight. There came finally the barometer of Fortin and later the aneroid which serves so well not only the mountain-climber, but also the airman. It is the pressure of this ocean of air in which we live which forces the water up into a pump on the upward stroke of the piston.

A principle enunciated by Bernoulli states that if a fluid be in motion, where the pressure within the fluid is large, the velocity will be small—a simple principle, and the reader may think it an unimportant one. In reality, this principle governs the action of the filter pump of the chemist, the ball poised in the water jet in the old-time lawn fountain, the atomizer with which we spray our throats, the curved ball of the baseball pitcher or tennis player, and the rotor ship which, by its rotating "mast" or shaft can run against the wind.

**Diffusion.** Quite as important to us is the great principle of diffusion. That gases and liquids diffuse into each other is a matter of everyday knowledge. It is a less known fact that a gas may diffuse into a solid. Palladium, for instance, absorbs 960 times its own volume of hydrogen. It is most astounding, however, that solids will diffuse into solids, as was shown by Sir Roberts-Austin in the case of gold and lead. These phenomena are but the result of the constant motion of the molecules of all matter, a motion existing at all temperatures except that of the "absolute zero"—a temperature of  $273^{\circ}$  below zero on the Centigrade scale, or  $459^{\circ}$  below zero Fahrenheit. Energy is transferred by this molecular motion. Are there other ways in which energy may be transferred? This question immediately suggests pulleys, ropes, belts, and factory shafting. By such means, indeed, energy may be transferred, but a much more important method is that continually exemplified about us in everyday life—the transfer by a wave motion in a material medium. This leads us most naturally to our second division, sound.

## Sound

**A Sound Wave—A "Longitudinal" Wave.** A vibrating body disturbs the air and sound waves transmit the emitted energy

to our ears by a so-called "longitudinal" wave, in which the particles of the air move to and fro *along the line of advance of the wave*. A system having a definite frequency of vibration will easily absorb energy from another system of the same vibration frequency. This principle holds in all physics, there being conspicuous examples in light and electricity also.

## Heat

**Heat—Molecular Energy.** A vital factor in man's life is what is called "heat"—which when added to a body raises its "temperature." By *temperature* we mean that heat condition, relative to its surroundings, which determines whether a body will receive more or less heat than it imparts. Several miles aloft the temperature is too low for man's comfort, while a few miles below the surface of the earth it is too high. Little does the average man realize the shallowness of the region in which life is possible for him. The temperature and pressure of our atmosphere determine the thickness of this habitable shell. Recall the tragic effort to scale the heights of Mount Everest.

**Molecules in Constant Motion.** It was in this study of heat that man's attention was early called to molecules and atoms. The kinetic theory of gases assumes that the atoms and molecules of matter in the gaseous state are in constant motion smashing up against each other and the walls of the confining receptacle. The average velocity possessed by a given kind of molecule at a given temperature and under a given pressure has a perfectly definite value and it is most interesting to note that the velocity of sound in a gas of a certain kind under these conditions is six-tenths of this molecular velocity.

Further, the molecules of matter in any state (solid, liquid, or gaseous) are in constant motion, as is shown by the Brownian movement. With a microscope we cannot see molecules themselves; but, if small particles of gamboge or gum mastic be suspended in water, these, owing to the irregular bombardment of the molecules of the water, appear to be in constant motion, like large push balls urged this way and that by invisible Lilliputians.

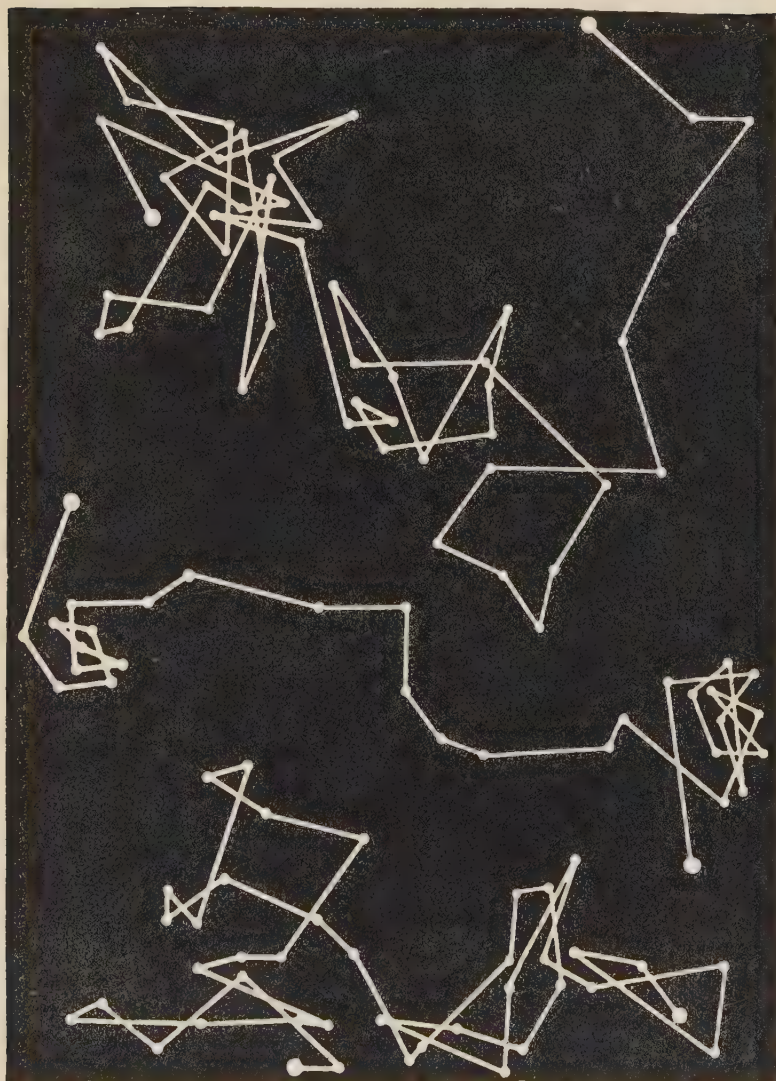


Figure 31. The Brownian Movement. A diagram constructed from actual observation, showing the erratic paths pursued by the very fine particles suspended in a liquid, when bombarded by molecules of the liquid. The seeming straight paths are, in reality, composed of many minute, zig-zag paths. (From Thomson.)

**Production of Heat.** This energy of molecular motion or heat may be produced in various ways. The Indians generated heat by friction; we often produce it thus, even against our will. We also produce it by chemical means, e.g., by burning fuel. We accept it gratefully when sent to us from the sun through the vast expanse of space, in a form which we call "radiant heat" or heat in the form of radiation, a wave in the "ether."<sup>2</sup> This wave is a "transverse" wave, the disturbance in the medium being in a direction *transverse*—that is, *perpendicular to the direction in which the wave is advancing*.

**Effects of Heat.** When bodies are heated, various changes occur, many of them familiar to us. Heating generally results in expansion or a change of state from solid to liquid, or from liquid to gas.

A thermostat is an instrument by which conditions are so regulated that any desired temperature can be maintained. We all actually carry with us an excellent thermostat—our own skin. Heat is required for evaporation; when our bodies are too hot, the skin (if acting properly) secretes perspiration; this evaporates, the heat necessary for the process being taken from the skin. We thus cool off. Quite a different result obtains, however, when much moisture is present in the atmosphere, and there is not only evaporation from the skin but at the same time condensation upon it, this latter process liberating heat. This is why we suffer in humid, hot weather.

**Interchangeability of Molecular and Mechanical Energy.** If the question were asked, "What physical principle most concerns man in this mechanical age?" the reply most frequently received would be "the interchangeability of heat and mechanical energy," which is the principle upon which steam and gasoline engines are constructed. In the former, by burning coal we heat water which, turning into steam, exerts a pressure upon the moving parts of the machine resulting in mechanical work; in the latter, the gasoline and air reacting chemically produce similar results. This change in the form of energy is not, however, the only possible one. In fact, energy of any one kind, mechanical, sound, heat, light, electrical, or magnetic may, directly

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<sup>2</sup> See page 163.

or indirectly, be transformed into any other kind by suitable devices.

## Magnetism

If a piece of lodestone (magnetite) be dipped into iron filings, the latter will cling to it. We do not know why. This property of attracting iron filings is called magnetism, and the body exerting this peculiar force is called a magnet. Lodestone is a natural magnet. Artificial magnets usually made of steel are familiar objects. Magnetism is a molecular property; for a blow with a hammer, thus shaking up the molecules, will demagnetize a magnet, and heating to a red heat will cause a bar of iron to lose its ability to become a magnet, unless the temperature be again lowered to a definite point. Furthermore, by the principle of "*magnetic induction*" we may produce a magnet by placing it in a magnetic "field"—that is, in a region in which there are magnetic forces—and a mechanical agitation aids the process. The usefulness of the magnetic compass, invented by the Chinese centuries ago and the guide of the mariner of old, depends upon the fact that the earth is a great magnet having its own magnetic field.

## Electricity

Electricity at present is quite as inexplicable as magnetism. One form of this so-called "electric" force we may see exerted by a piece of amber (the Greek word for which is "electron") when rubbed by a piece of fur or flannel. By the process of friction (contact alone, however, will suffice) a state of "electrification" is produced. Our belief is that the process underlying electrification consists in the removal or addition of small charged particles called "electrons." But the essence of the electron is a profound mystery, as is, of course, the entire basic structure of our world. When a body has an excess of electrons, it is said to be negatively charged; and when a dearth of them exists in it, we say that the body is positively charged.

**The Electron Theory.** One of the most brilliant achievements of the human mind is the invention of the electron theory,

which, although hardly more than thirty years old, is, in its practical ramifications, already exerting a profound influence upon civilization. This theory is discussed more fully in Chapter X. Suffice it here to state that the electron is conceived to be, or to possess, an *indivisible* bit, i.e., an “atom” of that form or manifestation of energy called “electricity.” We have succeeded in dividing the atom—which a few years ago was thought impossible. Why the electron, as a constituent of the atom, remains undivided or whether it is in fact “indivisible,” we do not know: the word merely connotes certain aspects of the behavior of the physical universe. Electricity is associated with mass. But the mass of a body does not depend solely upon its electrical charge and therefore cannot be calculated from this charge. We have discovered no way of describing this form of energy except in terms of certain natural phenomena characteristic of it.

### Electrostatics

**Charged Bodies at Rest.** Electrostatics deals with electricity at rest. Two bodies similarly charged mutually repel each other;

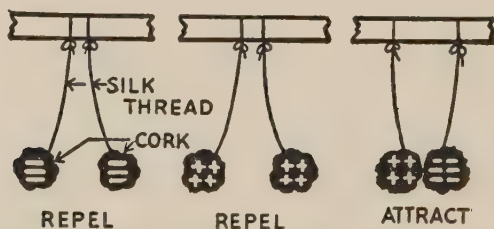


Figure 32. Electrostatics—Action of Negative and Positive Charges.  
(From Lunt.)

whereas two charged oppositely, one negatively, the other positively, mutually attract—each having a region about it, an “electric field,” in which electric forces hold sway. A *unit charge* in the “centimeter-gram-second” (briefly, c.g.s.) system is defined as being such a charge that, if two small bodies, each having this charge, be situated at a distance of one centimeter in air, they will repel each other with a c.g.s. unit of force, called the “dyne.” In an *electric*, as well as in the case of a magnetic field,

we have the phenomenon of induction. By *electric* induction, we mean the development of charges upon parts of an electrically neutral body by the influence of a body which is charged. These simple but important facts we merely mention in passing. What, however, we must emphasize is this: If a body be positively charged, for instance, it will repel another positively charged body. Therefore, to bring these bodies together, work must be done. Suppose a body having a *unit* charge of positive electricity be brought from a region infinitely remote, up to a certain point in the field of this positively charged body. The physicist calls *the work done upon the unit charge* in this process the "potential" of the point in question. This electrical potential has its analogy in *gravitational* potential. For instance, for a point above sea level the gravitational potential is measured by the work done in raising a unit mass, say a pound of water, up to that point from sea level against the pull of gravity. Water from a high lying lake will, under gravity, flow to a lake lower down. The electric case is quite analogous: A positive charge at high potential, will pass to a region of lower potential, if free to do so. Lightning is an example of this principle on a grand scale, electricity passing between clouds or between a cloud and the earth. Thunder is but the mechanical result, i.e., a sound wave due to the disruption of the atmosphere, as the charges move. This introduces us to a consideration of the electric current.

### Electric Currents or "Electrodynamics"

**Charged Bodies in Motion.** It is, in a way, unfortunate that Benjamin Franklin established the convention that a glass rod rubbed with silk would be said to be *positively charged*. Later the direction of flow of an electric current was defined as the direction in which positive charges move. An electric current in a wire does not, we now know, consist of *positive charges* moving from high to low potential levels, but rather of *electrons* moving in just the *opposite* direction. The die was cast long ago; it is now too late to change the convention then established. In liquids and gases, positively charged carriers do, indeed, move in the positive current direction but negatively charged carriers here also move in the opposite direction.

**Effects of Electric Currents.** An electric current heats the conductor carrying it, produces chemical effects, often dissociates a liquid, and produces a magnetic field in the region surrounding the conductor. This last mentioned fact was ingeniously used by Faraday to produce the mechanical motion of certain parts of a suitably constructed machine, the electric motor—a machine of tremendous and ever-increasing importance to mankind. Further, if a conductor which is part of a closed circuit which does not carry a current be mechanically moved in a certain direction in a magnetic field, a current is produced in the conductor. This discovery—that of “electro-magnetic” induction, also made by the brilliant Faraday—exemplifies the phenomenon of charges in accelerated motion. The practical result of this discovery was the invention, also by Faraday, of the electric dynamo, another boon to mankind. With the dynamo as an efficient and convenient means of producing a current, the arc light and, in due time, the incandescent bulb followed.

The inventions of the dynamo and motor are conspicuous illustrations of the enormous impetus given to the arts when new discoveries are made—often of mere theoretical interest at first, but resulting, eventually, in the development of mechanisms of great practical use.

Among the useful devices resulting from the research and experiments of physicists are the telegraph and telephone. Recently there has burst upon us a phenomenal “radio” development in which the electron in the three electrode vacuum tube plays again the master rôle—the details of which, although most fascinating, are beyond the scope of this brief survey.

## Light

**A Transverse Wave in the “Ether.”** Light as a physical phenomenon viewed by the older physics is a transverse wave in the “ether.” It is regarded as a *wave* because of the phenomenon of interference in which two waves from the same source interfere, producing at certain points luminous intensity which is the sum of the intensities of each wave separately and at other points is the difference of these intensities. It is regarded as a *transverse* wave because of the phenomenon of polarization, which may

be roughly described as a one-sidedness which characterizes the wave under certain circumstances. The luminous energy is transported in straight lines in free space with the enormous velocity of 186,000 miles, or 300,000 kilometers, per second, which is the same velocity as that with which "radio" waves move—a velocity, by the way, whose numerical value was assigned by Maxwell when he predicted the discovery of the so-called "electromagnetic waves."

Experience reveals three important phenomena which must be taken into account in light, viz., (a) "reflection" or the sending back, into a medium, of a ray of light which is incident upon a body; (b) "refraction" or the bending of the ray as it passes from one medium *into* another of different optical density; and (c) "diffraction" or the apparent bending of a ray when it passes by the sharp edge of a body.

**Practical Applications.** To avail ourselves of the benefits of these principles, complicated mechanisms have been developed. To the many who have made painstaking experiments, including the great Galileo, we are indebted for such instruments as mirrors and lenses, eye-glasses, the telescope and microscope, the photographic camera, stereopticons and moving picture machines, opera glasses and binoculars. The instruments, however, which have most broadened the boundaries of our knowledge of the *structure of matter* are the various kinds of spectroscopes—by which rays of light emitted by various substances are broken up and their behavior studied. Descriptions of one type or another of this instrument will be found in almost any standard text in physics.

Through the now known facts about light, the rainbow, the sun's reddish glow when setting behind clouds, the peculiar position assumed by comets' tails, the mirage of the desert, the brilliancy of the diamond, and a multitude of other once unsolved mysteries are no longer enigmas to us. He that hath eyes to see may now verily, if he so desire, *perceive* with the light of modern science flooding the world.

**Conclusion.** From the short survey given above, it will be evident that "the older physics" has in the past and must in the

future play an important and very practical rôle in man's life. It must also be clear that, whichever way we turn, we are always confronted with energy—mechanical, heat, magnetic, electric, light—which is interchangeable in form or manifestation and is assumed, in all that has been written above, to be *indestructible in quantity*. We see forces, balanced and unbalanced, tending to change the amount of motion or the “momentum” (mass times the velocity) which a body may have; and, although these forces may change the velocity of the body, our conclusions until just recently have been that *mass* also, as well as *energy*, is not subject to change—that *it, too, is indestructible*.

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Crew, *op. cit.*, pp. 123-125.  
Stewart, *op. cit.*, pp. 97-100.

## 12. What is meant by "inertia"?

Stewart, *op. cit.*, p. 67.Crew, *op. cit.*, p. 55.Kimball, *op. cit.*, pp. 4, 19.

## 13. What is meant by "momentum"?

Stewart, *op. cit.*, pp. 75, 150.Kimball, *op. cit.*, p. 58.

## 14. What is meant when it is said that one body is in equilibrium with another?

Kimball, *op. cit.*, pp. 24-25, 29, 36.Stewart, *op. cit.*, p. 11.Crew, *op. cit.*, pp. 80, 81.

## 15. What is meant by stable as distinguished from unstable equilibrium?

Crew, *op. cit.*, p. 134.

## 16. What are the main subdivisions of the subject-matter of "physics"?

See topical headings of Table of Contents in Kimball, pp. vii-xii.

## 17. What subjects does "mechanics" embrace?

Kimball, *op. cit.*, p. 10.

## 18. What are the two simple machines upon the principles of which all complex machines are built?

Stewart, *op. cit.*, pp. 109-114.

## 19. What is a lever and what machines illustrate its principle?

Stewart, *op. cit.*, pp. 109-114.

## 20. What is an inclined plane and what tools are essentially inclined planes?

Stewart, *op. cit.*, pp. 114-115.

## 21. What is a pendulum and what is one of its practical uses?

Kimball, *op. cit.*, pp. 86-87.E. S. Dana, *Text-book of Elementary Mechanics* [N. Y.: Wiley, 1908, 12th ed.],

Ch. IX, Pendulum, pp. 252-261.

## 22. What is "diffusion"?

Stewart, *op. cit.*, p. 190.Kimball, *op. cit.*, pp. 161-164.

## 23. What is "sound"?

Stewart, *op. cit.*, pp. 333-334.Webster, Farwell, and Drew, *op. cit.*, pp. 189-191.

## 24. What is "heat"?

Kimball, *op. cit.*, p. 279.Crew, *op. cit.*, pp. 295-297.

## 25. What is meant by "magnetism"?

Crew, *op. cit.*, p. 376.Stewart, *op. cit.*, Ch. XXV, Magnetism, pp. 360-378.

## 26. What is meant by "electricity"? Distinguish between electricity in motion and at rest.

Kimball, *op. cit.*, pp. 352-353.Stewart, *op. cit.*, Ch. XXVI, Electrostatics, pp. 379-406; Ch. XXVII, Simple properties of electric currents, pp. 407-415.

## 27. What is "electric potential"?

Crew, *op. cit.*, pp. 414-415.

28. What is meant by "electrolysis"?  
Crew, *op. cit.*, pp. 472-481.
29. What is meant by "electro-magnetic induction"?  
Crew, *op. cit.*, pp. 452-454.
30. What are some of the older theories of light?  
Webster, Farwell, and Drew, *op. cit.*, pp. 294-295; 650-652.

## CHAPTER X

### THE NEWER PHYSICS \*

**The New Based Upon the Old.** There is in reality no dividing line in Science between the past and the present—the old and the new—for the present is founded upon the past, as we advance step by step with the gradual unfolding of truth. Nevertheless, it has seemed proper to divide our subject into two parts both because of the extreme rapidity of the advance recently made and because of the revolutionary conceptions introduced. The results of this advance have been a greatly extended scientific horizon and a closer yoking of all branches of science, especially those of chemistry and physics. This truth is especially well illustrated in the discovery of radium by the chemist and the development of the vacuum tube by the physicist, both achievements resulting in the presentation of phenomena which could not be explained on the basis of old conceptions, and offering, in fact, a common challenge to scientific men of both groups.

### The Electron Theory

**A New Approach to the Study of Phenomena.** Foremost in this new stage has been the part played by a new hypothesis—"the electron theory," based on the conception that the atom (the theretofore assumed ultimate, irreducible, indivisible entity) is, in fact, made up of constituent particles which are arranged in certain definite ways. The existence of small, negatively charged particles was established by Sir J. J. Thomson; by him the assumed particles were called "corpuscles." That the existence of these particles was so general in nature was not fully realized until Zeeman was successful, in 1895, in obtaining an "effect" sought for without success by Faraday.

**The Zeeman Effect.** This so-called "Zeeman effect" consisted of a splitting up of a line in the spectrum of a substance

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\* By Professor Norton A. Kent (see note at head of Chapter IX).

when the source of light was placed in a magnetic field. Mathematical calculations yielded numerical data concerning the mass involved and its charge, and it became at once evident that the actor in this new rôle was none other than the corpuscle of Thomson. The name "electron," suggested in 1891 by Stoney, is now used and the experiment of Zeeman in 1895 is generally regarded as *the critical step* which resulted in the acceptance by scientists of the electron theory as a working hypothesis. On this theory the physicist now attempts to explain not only the phenomena of electricity and magnetism, but also those of light and radio-activity. In fact, manifestations of energy in the entire physical universe are now regarded as associated with the motion of electrons and their companions, the later discovered protons. These recent researches with which the past thirty years have been replete have given us, through their results, a new insight into the marvels of the material world in which we live.

Let us view briefly, in logical rather than chronological order the main facts in this theory—facts which according to our present knowledge we believe to be approximately true.

**Cathode Rays.** If a glass tube containing a gas at low pressure, has sealed into it two electrodes—one of a concave spherical shape and serving as the negative terminal (or cathode) of a high potential electric current—a result is produced which is explained as follows: Atoms of the gas are broken up. Electrons, shot out perpendicular to the spherical surface, and constituting the cathode rays or more properly, the cathode *stream*, converge upon an anti-cathode—a receiving surface within the tube made of some heavy metal, as for instance, tungsten. The electrons in this cathode stream move with great speed, even up to as high as a tenth the velocity of light, and when they are suddenly stopped, there are created at their point of impact the Roentgen or X-rays. These rays penetrate the glass walls of the tube as does sunlight. But they also penetrate many substances which are opaque to the longer waves to which the eye is sensitive and which give us the sensations of "light." Other substances are wholly or partially opaque to the X-rays. These, when placed to intercept the rays (as, for instance, between the cathode and a photographic plate), cast *shadows*. The result is

the "skiagraph," or shadow picture, which has been of inestimable value to the surgeon and physician.

**Electrons and Protons.** The mass of an electron as determined by careful measurement is one eighteen hundred and forty-sixth the mass of an atom of hydrogen. This statement will mean little to the average reader who is unfamiliar with such small masses. That some definite conception of such may be gained, let us start with a mass with which we are all familiar—that of a dime. This coin has a mass of about  $2\frac{1}{2}$  grams, the gram being a unit of mass in a centimeter-gram-second (or c.g.s.) system of the scientist. The mass in grams of an atom of hydrogen, is 1.66 divided by a million, million, million, million (that is 10 multiplied by itself six times taken four times over or 10 multiplied by itself 24 times) which is written  $\frac{1.66}{10^{24}}$  or  $1.66 \times 10^{-24}$  grams. Or, in other words, by a simple calculation, the mass of a dime is about  $3 \times 10^{27}$  or three thousand million, million, million, million times as great as that of an electron.

A proton has a mass 1,845 times as great as that of an electron. In fact, the proton forms all but  $1/1,846$  of the mass of a hydrogen atom.

**The Atom a Mechanism.** Of course, such minute bodies cannot be directly perceived by any of our senses, but their actions can be studied and the human mind can conceive of mechanisms such as atoms, containing electrons and protons. Such conceptions are essential in both chemistry and physics, and are mental achievements no more difficult than is the conception of the universe with its vast spaces and myriad worlds, as introduced to us by the astronomer.

**Electric Charges Associated with Electrons and Protons.** The electron always has associated with it a *negative* charge equal to  $4.774 \times 10^{-10}$  c.g.s. electrostatic units of electricity. The value of this charge was measured by Millikan in a series of brilliant experiments in which a small droplet (of oil or mercury, for example) was suspended between two electrically charged plates and its motion studied as it picked up electrons. The proton which, as previously stated, has a mass equal to

1,845/1,846ths the mass of the hydrogen atom, still bears but the same charge as the electron, a c.g.s. unit charge, equal to the value of the negative charge, but in this case positive. The diameter of the electron is about  $4 \times 10^{-13}$  centimeters, the centimeter being about two-fifths of an inch. The diameter of the proton is 1/1,845th as great as that of the electron.

**The Quantum Theory and Radiation.** The German, Planck, while studying the manner in which hot bodies radiate, came to the conclusion that when energy was emitted, it was always given out in definite amounts, called "quanta." This conclusion was revolutionary but the quantum theory soon found an important application in the "photo-electric effect" in which electrons were dislodged from atoms under the influence of ultra-violet light;

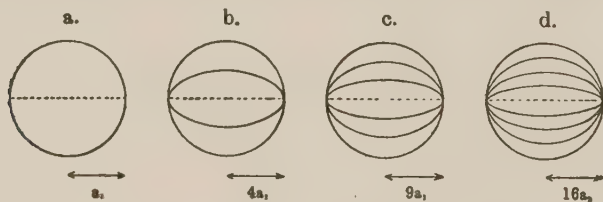


Figure 33. Electronic Orbits—after Bohr

and upon this quantum principle the Danish physicist, Bohr, built his theory of atomic structure and radiation.

**Bohr's Theory of Atomic Structure.** Let us start with the lightest of the atoms, hydrogen. This, Bohr conceived to consist of one proton and, revolving about it, one electron. The smallest orbit in which the electron moves is a circle of radius  $5 \times 10^{-7}$  centimeters. But, when the atom is excited by various means (such as, for instance, the passage of an electric current), the electron may revolve in a circular orbit 4 or 9 or 16 or 25, etc., times as great—the radii varying as the squares of the whole numbers, 1, 2, 3, 4, 5, etc., as shown in Figure 33. These orbits Bohr called "stationary orbits." To enable the reader to visualize the relative distances involved, it may be stated that if we should enlarge such an atom of hydrogen so that the proton became one millimeter (1/25 of an inch) in diameter, the electron would be about 6 feet in diameter, and lie when in its smallest

orbit, at a distance of 15 miles from the proton. But the circular orbits are not the only stationary orbits. The path of the electron may be an ellipse as shown in Figure 34-b or one of either



Figure 34. Electronic Orbits—after Bohr-Sommerfeld

of the two ellipses (Figure 34-c) or any of the three ellipses, of different eccentricities (Figure 34-d). The major axes of these

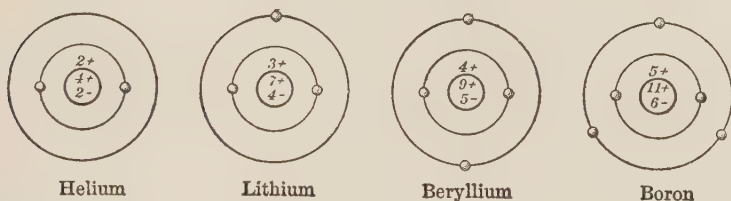


Figure 35. Atomic Structure of Helium, Lithium, Beryllium, and Boron—after Bohr

sets of ellipses are the same as the diameters of the circular orbits of each respective set. Further, the proton always lies at the center of the circle or at a focus of the ellipse.

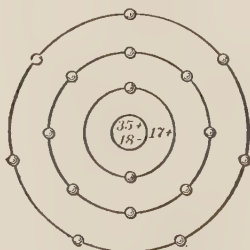
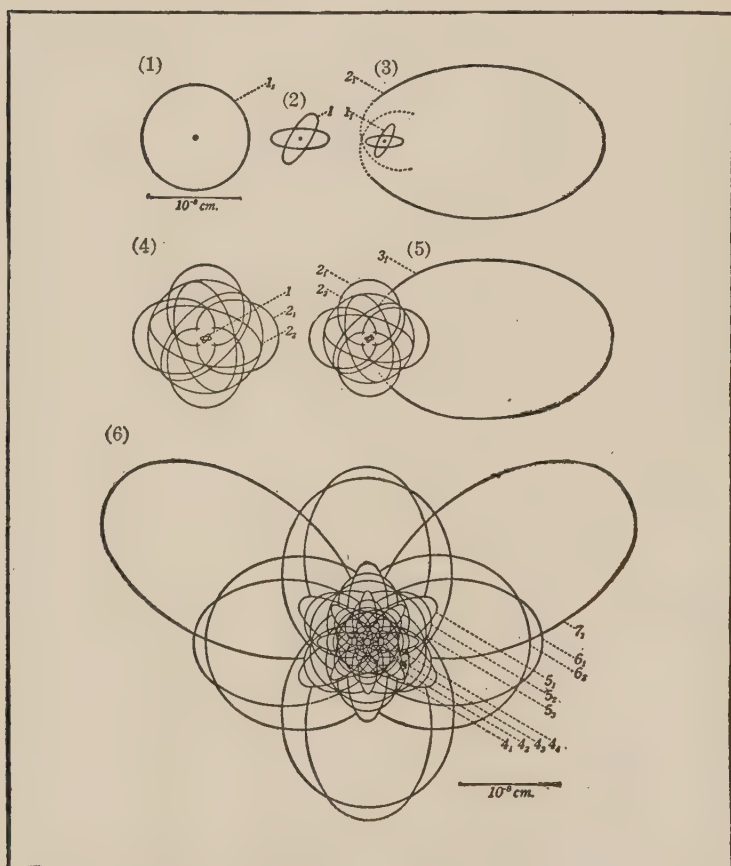


Figure 36. The Chlorine Atom—after Bohr

**Differences in Atomic Structure.** Following hydrogen (the lightest atom with its one proton and one electron) comes helium (the second lightest), having for its internal structure or nucleus four protons and two electrons, and, in outlying orbits, two more

electrons. Its nucleus possesses, then, a mass about four times that of the hydrogen nucleus, and an excess positive charge of two, this neutralized by the outer or "valency" electrons.



diameter. Why six *or* seven protons with three *or* four electrons in its nucleus? "Thereby hangs a tale" which is told in Chapter XII (see page 201). As we pass to systems of greater atomic weight the complexity of the nucleus increases, more protons and electrons exist therein, and the electrons both near and relatively far from the nucleus increase in number in a regular and consistent manner.

**Moseley and Atomic Numbers.** The excess of protons in the nucleus over the electrons therein, is always numerically the excess positive charge on the nucleus; and, of course, in a neutral atom, this excess equals the number of electrons in the orbits surrounding the nucleus. Further, the atoms—beginning with the lightest, hydrogen, and running up to the heaviest, uranium—when arranged in order of their excess positive nuclear charge, form a progression from 1 to 92. That this order of the elements is intimately connected with the excess positive charge in the nucleus was pointed out by the famous young Englishman, Moseley, and these "atomic numbers" are now recognized as being more fundamental than the atomic weights.

**The Bohr Theory of Radiation.** When an atom, of hydrogen for instance, is in its undisturbed or "unexcited" state the electron is assumed to revolve in its smallest stationary orbit, the innermost circle; when excited, however, by excessive heat, for instance, or the passage of an electric current through the gas in a vacuum tube at low pressure, the electron has energy added to it. The atom is then said to be excited or "ionized" either *partially*, so that the electron revolves in one of the outer circular or elliptical orbits, or *completely*, in which latter case it has been torn away so far that it may not return to its proton. When it falls back either into a stationary orbit about its own proton, or into an orbit about some other proton at that time devoid of an electron, energy is emitted. This may happen when it leaves its position, during transit, or upon its arrival in its new orbit—the Bohr theory does not tell us which; but we do know that this energy emission takes place according to a certain law, namely, that the changes of orbit are associated with the emission of *definite amounts* of energy.

**Consistency of the Bohr Theory with Spectroscopic and Other Observations.** This theory is consistent with the observed spectroscopic results and in fact is based upon them, for the position of a line in the spectrum of a substance is determined by the length of the wave of light sent out which depends upon the frequency,  $\nu$ , or the number of vibrations per second which characterize the wave; and the exact amount of energy emitted, represented by  $E$ , can be calculated from the now famous equation of Planck:  $E = h\nu$ . In this equation,  $h$  is Planck's constant—a definite constant in nature, the value of which is quite accurately known. The Bohr theory has served as a powerful aid in our effort to extend the bounds of our knowledge. Similarly, applying the Bohr theory to atoms other than hydrogen, electrons in both the inner and outer orbits may be displaced by the addition of energy; and, when they fall back to their previously occupied or other innerlying orbits, they emit energy. As these orbits are characterized by greater or lesser energy, they are often referred to as “energy levels.”

### Atomic Systems

**Electrons and Protons Form Atomic Systems.** If we accept the Bohr theory of atomic structure, we must conceive of matter as composed of atoms or organized systems of atoms called molecules, each atom being made up of electrons and protons which have mass, possess energy, and are bound together by forces roughly, we may say, such as those which bind the planets in our solar system. But we must carefully note that the astronomer's conception of the motions of the planets in our solar system is simplicity itself, compared with the physicist's conception of the motions of electrons about the nucleus of an atom and the motions of atoms in the molecule.

**The Dynamical Theory of the Physicist and the Statical Theory of the Chemist.** The dynamical theory above outlined seemed, until very recently, to meet more nearly than any other the requirements of the physicist. But in the past many chemists have felt that their needs were better met by a statical theory, such as that put forward by Lewis and Langmuir, in which the elec-

trons occupy positions more or less fixed in "shells" and not rotating in orbits about the nucleus. A discussion of this theory will be found in Professor Newell's chapter (see page 196). An interesting feature of the Lewis-Langmuir theory is that chemical reactions are governed by the simple principle that each element appearing in a compound strives (by giving up from, or taking into, its outer shell one or more electrons) to reach the configuration of an inert gas which always has eight electrons in its outer shell; and it is a fact, acknowledged by chemists and physicists alike, that the outer lying electrons are those which play the most important rôles in chemical processes. The dynamical atom of the physicist has not been entirely satisfactory to the chemist for explaining reactions. The static (Lewis-Langmuir) theory has served him better as a working hypothesis. On the other hand, an orbit theory appeared until recently essential to the physicist.

**The Laws of the Conservation of Matter and Energy.** With reference to the problem of isotopes (see Chapter XII), it may be stated that Aston has just recently found (1927) that the atomic weight of hydrogen is 1.00788 on the basis of oxygen as 16 and, on the same basis that of helium 4.00216. The only scientific hypothesis consistent with the results of experimentation is that helium is composed of four hydrogen atoms, the four protons of which, packed together, form the helium nucleus. Now  $4 \times 1.00778 = 4.03112$ . Where has gone, then, the .02896? Has matter been annihilated? The answer, on the basis of our present-day knowledge, is "yes," that is, it has been transmuted into energy. This means that the law of the conservation of matter, upon the truth of which we confidently relied, no longer holds in the sense formerly assigned to it. The present theory is that when mass disappears, energy is created. If matter is energy, the destruction of mass is fully consistent with the creation of energy. Aston gives a simple calculation as follows: If the hydrogen atoms in 9 cubic centimeters of water could be packed together by man so as to form atoms of helium, 200 kilowatt-hours of energy would be created. But the detonating effect of such an experiment would be such that the "whole of the hydrogen on the earth might be transformed at once, and the success of the experiment published at large to the universe as a

new star," our earth and heavens being "rolled together with fervent heat." So tremendous are the storehouses of energy within the atoms of the elements, that if these storehouses could be unlocked, mankind would have no further need of coal. Sad to relate, however, the forces involved in releasing this energy would probably be so great as to be beyond our control.

**The Transmutation of the Elements.** The aim of the ancient alchemist was to change the baser metals into gold—this

Substance	Radioactive constant in (seconds) <sup>-1</sup>	Half-value period	Radiations emitted	Range of alpha particles in air in centimeters
Uranium 1.....	4.3 × 10 <sup>-18</sup>	5 × 10 <sup>9</sup> years	α	2.37
Uranium Y.....	5.4 × 10 <sup>-6</sup>	1.5 days	β (slow)	
Uranium X <sub>1</sub> .....	3.3 × 10 <sup>-7</sup>	24.6 days	β (slow)	
Uranium X <sub>2</sub> .....	1.0 × 10 <sup>-2</sup>	1.15 min.	β	2.75
Uranium 2.....	1 × 10 <sup>-14</sup>	2 × 10 <sup>6</sup> years	α	
Ionium.....	1 × 10 <sup>-13</sup>	2 × 10 <sup>3</sup> years	α	
Radium.....	1.26 × 10 <sup>-11</sup>	1730 years	α	3.13
Radium emanation.....	2.085 × 10 <sup>-6</sup>	3.85 days	α	3.95
Radium A.....	3.85 × 10 <sup>-3</sup>	3.0 min.	α	4.50
Radium B.....	4.33 × 10 <sup>-4</sup>	26.7 min.	β (slow)	6.57
Radium C <sup>a</sup> .....	5.93 × 10 <sup>-4</sup>	19.5 min.	β	
Radium C <sub>2</sub> .....	8.3 × 10 <sup>-3</sup>	1.4 min.	β	
Radium C <sub>1</sub> .....	.....	10 <sup>-6</sup> sec.	α	
Radium D.....	7.3 × 10 <sup>-9</sup>	16.5 years	β (slow)	
Radium E.....	1.6 × 10 <sup>-6</sup>	5.0 days	β (slow)	3.58
Radium F (polonium)....	5.90 × 10 <sup>-8</sup>	136 days	α	
?Lead.....	.....	.....	.....	.....

Figure 38. Transmutation of Elements—Disintegration Products of Uranium

<sup>a</sup> The production of radium C<sub>1</sub> from radium C is attended by the expulsion of a beta particle only. The expulsion of an alpha particle from Radium C produces radium C<sub>2</sub>. As this alpha particle gives rise to the branch series only, it is omitted from the table to avoid confusion.

for his own benefit. The dream of the modern alchemist is the transmutation of all the elements. But his object is both to satisfy his desire for knowledge and also, ultimately, to bring about great and abiding benefits to his fellow men. Many of the dreams of the modern alchemist have already been fulfilled in part, for Rutherford, by firing minute projectiles—helium nuclei—into nitrogen and other atoms, has produced hydrogen.

**Spontaneous Transmutation.** There are, however, complicated systems, namely those of the so-called "radioactive fam-

ilies" of the elements uranium and thorium which are spontaneously disintegrating. For instance, given a mass of uranium, in about five thousand million years, half of this uranium will have spontaneously changed into another element, uranium  $X_1$ ; half of this will in turn change in about twenty-four days to uranium  $X_2$ , and so on. Similarly with thorium and its descendants or "disintegration products." The end products of these two families are, all of them, forms of radioactive lead, the atomic weights varying from 206 to 210.

To chemists all honor is due for their laborious and painstaking investigations in this field.

### Particles and Rays

**Becquerel "Rays."** These radioactive transformations are accompanied by three distinct sets of phenomena—unseparated at the time of their discovery by Henri Becquerel. These phenomena are: (a) the emission, at great speeds from the complex nucleus of the atom, of *alpha particles* which are the nuclei of helium atoms carrying a double elementary positive charge, as the two valency electrons are lacking; (b) the emission, at still greater speeds (even up to nine-tenths the velocity of light), of *beta particles* which are electrons; and (c) the development of an ether wave of very short wave length, of the order of  $1/6,000$  that of visible light, called the *gamma rays*. This is the ray which has been used so successfully in curative medicine. The emission of an alpha particle, that is, a helium nucleus, from an atom results in an element of "atomic weight" four units less, and an "atomic number" smaller by two, the explanation being that the  $\alpha$  particle contains four protons and bears a double elementary positive charge.

**Roentgen or X-rays.** It is now but natural for the reader to ask: "What happens when an electron is shot into the nucleus of an atom? Are ether waves created?" The answer is "Yes"; waves in general of very short wave lengths, the so-called "X-rays." These rays are of two kinds: (1) the "general" radiation, composed of an infinite number of wave lengths (and the same for all elements); and (2) the "characteristic" radiation—

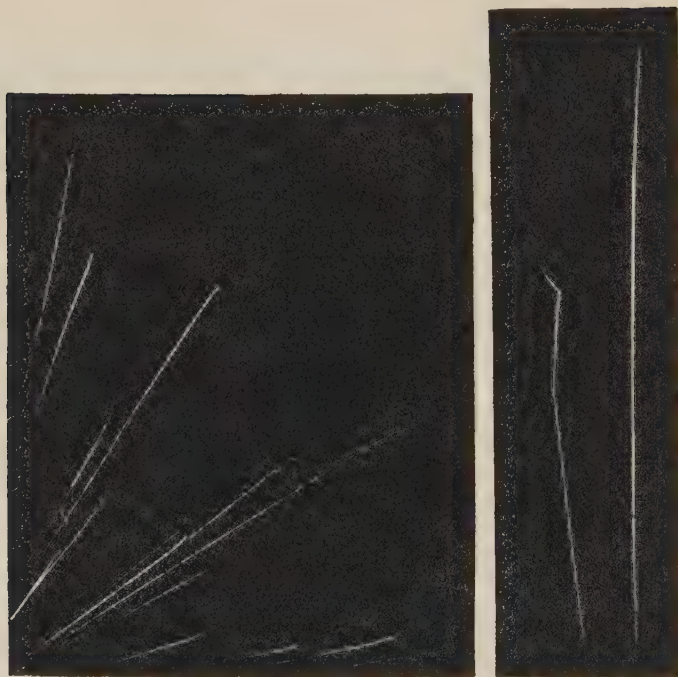


Figure 39. Tracts of Alpha Particles. (From Millikan.)

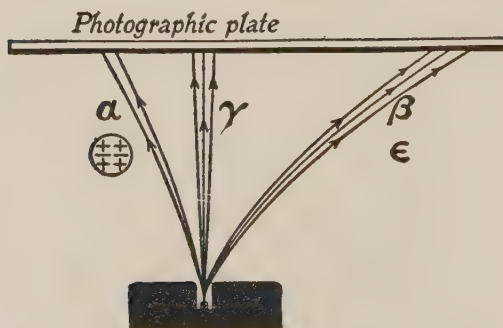


Figure 40. Becquerel Rays

Diagram of apparatus for separating and studying the different kinds of rays from radium. The radium is put in a small hole in a piece of lead, and a magnet so placed that the rays pass between its poles, the lines of magnetic force being directed into the page and being perpendicular to it. The positively charged helium nuclei,  $\alpha$  particles, are deflected to the left of the reader and the electrons,  $\beta$  particles, toward the right, as shown in the above diagram. The  $\gamma$  rays are not influenced by the magnet, and hence strike the photographic plate directly above the radium.

characteristic of the element bombarded by the electrons. It was this characteristic radiation which enabled Moseley to place many of the elements in a series according to their atomic number, for the cathode stream, driven against an element set as a target in the vacuum tube, resulted in the emission by this element of a characteristic radiation—the frequency of the radiation varying with the structure of that region of the atom immediately outside of the nucleus. The so-called X-ray spectroscope shares with spectroscopes of earlier types previously mentioned the honor of

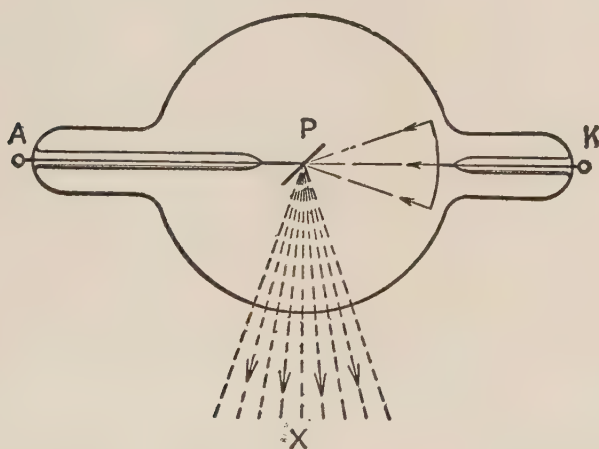


Figure 41. A Simple X-Ray Tube. (From Spinney.)

being one of the two most powerful tools in the hand of the physicist today.

**Spectra—the Keys to the Inner Chambers of Atomic Structure.** By various methods of excitation, one, two, three or more of the valency electrons are partially or entirely torn off from their atoms and as these fall back into various stationary orbits various spectra are produced. These spectra reveal to us the structure of the atoms.

**Is Light a Wave Motion?—Einstein's Theory.** As we thought light to be a wave motion we were forced to postulate the existence of the "luminiferous ether" as a medium in which

the wave could advance. The question then arose, "Is the earth drifting through the ether or carrying it along?" This problem was first attacked by Michelson and Morley. Their experiment and those of others yielded results at the time considered inconsistent with those obtained from other kinds of experiments. There then entered upon the scene the theories of the renowned German physicist and mathematician, Einstein.

**Theories of Relativity.** On the basis of the postulate that the velocity of light in open space is independent of the velocity of the observer or the source, Einstein developed a theory called

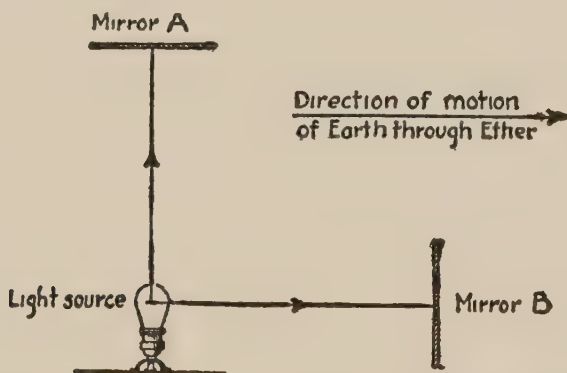


Figure 42. The Michelson-Morley experiment in which no relative motion between the Earth and the ether was detected. The time required for light to travel from the light source to and from mirror *A* was found to be the same as required to travel an equal distance to and from mirror *B*. If there is an ether drift, the latter time should be greater.

by him "The Special Theory of Relativity" and, some years later, a "General Theory of Relativity." By these theories the apparently inconsistent results of various experiments have been reconciled.

**Application of "The Special Theory."** The special theory was first worked out in much detail from specific data. Later Einstein universalized this in the epoch-making volume which bears the title last above given. "The special theory" leads us to these conclusions: (1) that to an observer, say *K* (in motion with reference to another, *K'*), a meter stick carried by *K'* seems shortened in proportion to the velocity of *K* with reference to

$K'$ ; and that, conversely,  $K$ 's meter stick appears less than a meter long to  $K'$ ; and (2) that a clock carried by  $K'$  appears to  $K$  to tick more slowly than  $K$ 's own; and conversely,  $K$ 's clock appears to  $K'$  to run slow. The changes in length and time between the systems of observers  $K$  and  $K'$  may be calculated by means of the so-called "Lorentz transformations"—developed, however, by Lorentz before the theory of relativity was announced by Einstein. This theory leads us also to another conclusion: (3) that a body fixed in  $K$ 's system increases in mass as determined by  $K'$  when  $K'$  is moving with respect to  $K$ , and vice versa.<sup>1</sup>

**Application of "The General Theory."** The general theory carries us farther: It leads to the conclusion that: (4) a ray of light is bent when it passes through a region in space in which

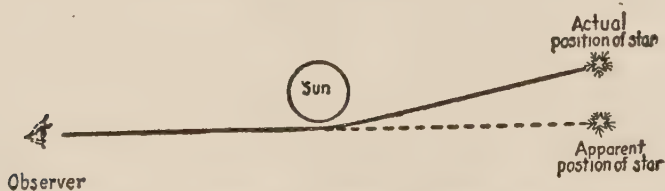


Figure 43. Diagram to illustrate the apparent displacement of a star from the Sun, by the bending of light toward the Sun

there are gravitational forces; (5) the major axis of the orbit of a planet should very slowly rotate or "precess"; and (6) the wave lengths of light emitted by a given source should be greater when the source is in a strong gravitational field than when in a weak one. All of the foregoing conclusions are in full accord with experiments performed—some before and the others after the enunciation of these theories. With regard to conclusion (3), it was shown some years ago that the mass of an electron increased as its speed with reference to the observer increased; conclusion (4) was verified at two recent eclipses, the rays of light from certain stars being bent when passing through the gravitational field of the sun. For years, the precession of the "perihelion" point of the planet Mercury (that point at which it is nearest the sun) had been, to the astronomer, an unsolved

<sup>1</sup> If the mass of a baseball were a pound when at rest with reference to the batter, it would gain an ounce in mass as judged by this batter if he struck it such a blow that it would leave his bat with one-third the speed of light or about 65,000 miles a second—an impossible feat, of course.

problem. Conclusion (5) cleared up this mystery. The last conclusion (6) has found verification just recently—it having been shown by Adams, at the Carnegie Solar Research Observatory, that certain lines in the spectrum of the companion of the star Sirius are much displaced to the red. The “Theory of Relativity” is becoming more and more closely interwoven into the fabric of modern physics.

**The Compton “Effect.”** If we accept the theory of relativity, the famous experiments performed by Michelson and others on “ether drift” could be expected to yield only negative results and our postulate of a luminiferous ether receives a severe blow.

There has recently entered the arena a rejuvenated and beautified corpuscular theory of light. The wave theory is being retained along with the new theory because it seems necessary in explaining some phenomena, notably that of the “interference” of light. In the new theory a light ray is described as a stream of quanta. The experiments of Compton and others (while being just what we should expect by the new theory) can apparently in no way be explained by the old. The evidence of the corpuscular theory, together with the acceptance of the theory of relativity, creates doubts in our minds as to the objective reality of the ether. As a scientific hypothesis the old ether theory is “weighed in the balance and found wanting.”

### Present Status of Physics

**Difficulties Presented.** Finally, a few years ago, it became evident that the classical quantum theory presented difficulties, not only because it could in no way explain the phenomenon of interference, but also because it could not solve other vital problems presented to it. The situation was temporarily somewhat relieved by the idea put forward that the electron not only revolved in an orbit but also rotated upon its axis. Still the quantum theory afforded no direct or exact means of calculating the intensities of the lines in the spectra of the elements. The highly artificial and ingenious quantum mechanics of Heisenberg then followed and solved this problem, but at the same time

plunged the physicist into bewildering abstractions. Before the publication of the Heisenberg papers, however, there had been developed by de Broglie the so-called "wave mechanics." Upon this theory, and extending it, Schrödinger framed a mathematical equation, which represented a great advance.

**A New Theory of Wave Mechanics.** In 1927, several physicists, prominent among whom were Born, Dirac, and Jordan, developed a theory combining the work of both Heisenberg and Schrödinger. The mathematical equations of this new theory have apparently solved every problem to which they have been applied. This is an astounding achievement. It illustrates in a most unique manner the fact that, first, the present is founded upon the past—previous work extending over many decades being involved in the production of the results obtained, and that, secondly, present-day physics has its roots deep in the field of mathematics. An adequate presentation of this most recent theory, so highly mathematical and technical in its nature, is totally beyond the scope of this outline of physics. The reader will find able presentations of parts of this subject in *The World of Atoms* by Haas, and *Wave Mechanics* by Biggs. For the most recent advances one must consult original papers recently published.

**General Statement.** We must content ourselves with a few general statements as to the new ideas introduced and the results achieved.

First, the discrete orbits of the Bohr theory postulated in cold blood, as it were, and for no known reason other than that revelations of the spectroscope seem to demand such orbits—these stationary orbits of the electron no longer preserve their former clear-cut definiteness with which our minds regarded them.

Second, the "energy levels" occupied by the electron in the atom *are* retained and are thoroughly justified.

Third, it looks as if, indeed, the luminiferous ether would no longer be needed as a mechanism for the propagation of waves, the old undulatory theory having been laid aside.

Fourth, electrons appear to have some of the properties of waves; for instance, their distribution is governed in certain cases by the laws of optics.<sup>2</sup> In fact, moving particles in general ap-

pear to have some of the properties of waves and, conversely, light, in certain aspects, resembles material particles.

Fifth, as we proceed in our measurement of physical quantities more completely into the realm of the submicroscopic, we meet an unexpected obstacle—the difficulty being formulated by Heisenberg as the “Principle of Uncertainty.” The accuracy of our measurement is limited in a curious way: if we decide to measure one quantity *very* precisely we are, for that very reason, prevented from measuring another quantity with accuracy, and the details of our physical world become in their essence unpredictable. The further we proceed into the microcosm, the more is this principle evident; while, conversely, the further we advance into the macrocosm, the less becomes the relative importance of the uncertainty; and the world, as we know it in the gross, appears to us orderly and subject to law.<sup>3</sup>

### Summary of Evidence in Support of the Electron Theory

Let us summarize briefly, to the end that the coherence and simplicity of the electron theory may be more apparent.

1. We are led to believe that *molecules* actually exist by reason of the Brownian movement. Streams of atoms also have been developed and studied.

2. That atoms of electricity, electrons, exist is shown by the fact that the cathode stream particles, the beta particles in radioactivity, the particles the action of which produces the Zeeman effect and those with which Millikan dealt, all bear the same electric charge and, under given conditions, have the same apparent mass.

3. Sound waves are produced by mechanical vibration. It is most natural, then, that radio and light waves should be produced by vibrating electrical charges. The emission of radiation by all hot bodies suggests that matter is made of electricity. The series of waves in the ether, (if such a medium indeed exists), sometimes called the ether gamut, extending progressively from those of shortest wave length (from the *cosmical* rays which have recently been studied so successfully by Millikan, to the *gamma*

<sup>2</sup> See C. Davison and L. H. Germer, *Physical Review*, Vol. 30, No. 6, Dec. 1927, pp. 705-740.

<sup>3</sup> See P. W. Bridgman, as listed under Select Bibliography.

rays emitted during radioactive disintegration) through the X-ray region, the ultra-violet, the visible (called *light* waves), the infra-red (called *heat* waves), up to the radio waves of great wave length (all these being called electro-magnetic waves), this series presents to us a spectacle of simplicity and uniformity.

4. Thomson's and Aston's researches, with those of others, show the existence of positively charged particles among which the alpha particles are most prominent. These particles are all more massive than the electrons and suggest the nuclear theory of the atom.

5. We should expect atoms of similar external structure, but dissimilar nuclei, to exist. The objective reality of isotopes justifies our expectations.

6. As we pass from the lighter and simpler atomic systems to those more massive and complex, we might expect a spontaneous disintegration. The radioactive elements here enter to confirm us in our reasoning.

7. Electrostatic forces suggest a planetary system. This theory answers the question, "How are the parts of an atom held together?" But just why radiation does not take place to such an extent that the planetary electrons fall into the nucleus is *not* clear. However, if we assume that atoms and molecules have definite amounts of internal energy, that molecules can rotate with only certain definite angular speeds and that electrons can only revolve in definite orbital periods, we are directly led to Planck's conclusion that energy is emitted solely in chunks, or "quanta." In the validity of this we are confirmed by the fact that bodies only radiate when they are hot and that certain kinds of spectra show a finite number of images of the slit of the spectroscope, that is, a finite number of spectrum lines.

8. The new corpuscular theory of light then follows quite naturally, the ejected entities being energy quanta.

9. Then comes the application of the quantum theory to the photo-electric effect in which the energy is *absorbed* by the body only in quanta. We have observed the phenomenon of light absorption producing atomic explosions, with the ejection of electrons at speeds which depend upon the frequency of the incident light. The more energetic waves, those of the shorter wave lengths (of larger quantum values), that is, the X-rays and

gamma rays, cause the ejection of electrons with speeds which approach the velocity of light. We cannot see how this is possible on the basis of the old and simple wave theory. Radiation we now believe, therefore, must consist of the emission of chunks of energy, the values of these being inversely proportional to the wave lengths.

10. Bohr's theory then describes the mechanism of radiation as consisting of sudden jumps from one orbit or energy level,  $W'$ , to another,  $W''$ , attended by the emission of radiant energy,  $E$ , according to the law,  $W' - W'' = E = h\nu$ .

The lines of the spectrum give the values of  $\nu$  from which we can calculate the values of the energy from a knowledge of the value of  $h$  obtained from other experiments.

11. Most recent advances indicate the reasonableness of our belief in the existence of energy levels, but the orbits of electrons and protons lose the definiteness formerly associated with them. Can we go further and get a definite and consistent conception of the architecture of the different atoms which give the vast array of spectra we have observed? This problem is being vigorously attacked at the present time.

### The Universe an Ever-Changing Order

"The old order changeth, giving place to new." This is an ancient conception, but it contains a principle with which we must reckon when dealing with fundamental truth. It applies to the universe as visioned by the mind, as well as to the objective facts with which the mind has to deal. Its recognition is basic to a scientific understanding of the past, and upon it depends all sane thinking about the future. Discovery of the order in which change has come about has revolutionized science. We may be on the threshold of discoveries which will still further modify our conception of inanimate nature. At least this is certain: more and more, those in touch with the onward march of science stand in adoration of the majesty of the universe. Whatever be the basic conception in the minds of a people by which consecration to belief in the moral order is taught, scientific contemplation of the universe is awe-inspiring. We are daily astounded at the complexity, and still more so, at the extreme simplicity

Type	Oc- taves	Wave length range in A.U. (1 A.U. = $10^{-8}$ cm.)	Generation	Detection
Cosmic (Millikan)..	..	0.0004-0.00067	Cosmic condensation of 4 H to 1 He? Combination of + and - charges? High potentials in thunderstorms (Wilson-Rutherford)?	Observed day and night. Penetrate, 6 ft. of lead. Discharge electroscopes.
$\gamma$ -rays.....	..	0.01-1.4 0.06-0.5 used in radiology	Emitted when atomic nuclei disintegrate (radioactivity).	As for x-rays, but more penetrating.
X-rays.....	14	0.06-1019	Emitted by sudden stoppage of fast moving electrons	a. Photography. b. Phosphorescence. c. Chemical action. d. Ionization. e. Photoelectric action. f. Diffraction by crystals, etc.
Ultraviolet rays....	5	136-3900	Radiated from very hot bodies and emitted by ionized gases.	Same as x-rays a to e: reflected, refracted, and diffracted by finely ruled gratings.
Visible rays.....	1	3900-7700 Violet 3900-4220 Blue 4220-4920 Green 4920-5350 Yellow 5350-5860 Orange 5860-6470 Red 6470-7700	Radiated from hot bodies and emitted by ionized gases.	Sensation of light; same as ultraviolet rays.
Infrared rays.....	9	7700- $4 \times 10^6$	Heat radiations.	Heating effects on thermocouples, bolometers; etc. Rise in temperature of receiving body. Photography (special plates). Reflected, refracted, diffracted by coarse gratings.
Solar radiation.....	..	Limiting wave lengths reaching earth 2960-53000		
Hertzian waves....	28	$1 \times 10^6$ to $3 \times 10^{14}$	Spark-gap discharge oscillating triode valve, etc.	Coherer. Spark across minute gaps in resonant receiving circuit. Reflected, refracted, diffracted.
Short Hertzian.....	17	$1 \times 10^6$ to $1 \times 10^{11}$		
Radio.....	11	$1 \times 10^{11}$ to $3 \times 10^{14}$	Same.	Coherer. Conversion to alternating current. Rectification with or without heterodyning and production of audible signals.
Electric waves.....	..	$3 \times 10^{14}$ to $3.5 \times 10^{16}$	Coil rotating in magnetic field.	Mechanical. Electrical. Magnetic. Thermal effects of alternating currents.

Figure 44. Range of Electromagnetic Waves—after Clark

of the mechanism in and through which energy manifests itself, whatever be its form. To each searcher after truth, whatever be the field in which he labors, the dominating purpose is to make available to mankind a better knowledge of the world as man's environment. And whether one's attitude reflects the material or the spiritual, the same conclusion is reached—a conclusion basic to all reasoning: that we live in a universe which, as we know it in everyday life, that is, in the realm of the macroscopic, reveals itself to us always as Order, the order ever changing according to fixed and definite law.

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2. What were the contributions of J. J. Thomson, Faraday, and Zeeman, respectively, to the electron theory?  
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G. C. Foster and A. W. Porter, *Elementary Treatise on Electricity and Magnetism* [N. Y.: Longmans, Green, 1909, 3d ed.], pp. 605-608.
3. Who suggested the name "electron" and what is its derivation?  
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Kimball, *op. cit.*, p. 352.
4. What are "Roentgen rays"?  
Crew, *op. cit.*, pp. 636-637.
5. What is (a) an "electrode"; (b) a "cathode"; (c) an "anode"?  
Crew, *op. cit.*, p. 444.
6. What is a "cathode stream"?  
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7. What is the mass of (a) an electron; (b) a proton?  
Crew, *op. cit.*, pp. 535, 550, 653.  
Webster, Farwell, and Drew, *op. cit.*, pp. 528-532, 562.
8. What electric charges do the electron and proton always carry?  
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O. M. Stewart, *Physics, a Text-book for Colleges* [N. Y.: Ginn, 1924], p. 569.
9. Is it assumed that the mass of every electron and every proton is the same, however these may be combined in atomic structure and wherever found?  
Kimball, *op. cit.*, p. 551.
10. What is "the quantum theory" developed by Planck and applied by Bohr?  
Crew, *op. cit.*, p. 645.  
Kimball, *op. cit.*, pp. 323, 555, 694-696.

11. What is "the Bohr theory" of atomic structure and, in this theory, what is the architecture of the simplest atom—that is, hydrogen?  
Crew, *op. cit.*, pp. 647-651.
12. What is meant by "valency electrons" whether the term is used in the Bohr theory or the Lewis-Langmuir theory?  
Webster, Farwell, and Drew, *op. cit.*, p. 631.
13. What is meant by "atomic number"?  
Webster, Farwell, and Drew, *op. cit.*, p. 556.
14. What is meant by an "ion," and when is an atom said to be "ionized"?  
E. S. Ferry, *General Physics* [N. Y.: Wiley, 1925], pp. 392-393, 463-464.  
Webster, Farwell, and Drew, *op. cit.*, pp. 427-429, 524, 525.
15. What is meant by an "isotope"?  
Webster, Farwell, and Drew, *op. cit.*, pp. 559-561.
16. How must the laws of the conservation of energy and the conservation of matter be modified in the light of recent discoveries?  
Webster, Farwell, and Drew, *op. cit.*, pp. 515, 516, 570, 571.
17. Why is the atomic change which takes place in radioactive substances called "spontaneous transmutation"?  
Webster, Farwell, and Drew, *op. cit.*, p. 558.
18. What are the three sets of phenomena to which together are given the name "Becquerel rays"?  
Webster, Farwell, and Drew, *op. cit.*, pp. 552-554.
19. What is meant by an "alpha particle," a "beta particle," "gamma rays"?  
Webster, Farwell, and Drew, *op. cit.*, p. 553.
20. What are the essential parts of an X-ray spectrograph or spectrometer?  
Webster, Farwell, and Drew, *op. cit.*, pp. 599-600.
21. How are the lines of all spectra explained by our present discoveries?  
Webster, Farwell, and Drew, *op. cit.*, pp. 622-629, 637-638.
22. In what sense may the spectroscope be said to enable the physicist to look into the inner regions of the atom?  
Webster, Farwell, and Drew, *op. cit.*, pp. 639-649.
23. How does the theory of "relativity" apply to an atom as well as to comets and planets?  
E. N. da C. Andrade, *The Structure of the Atom* [N. Y.: Harcourt, 1923, 3d ed. rev.], p. 215.
24. What are the general conclusions of Einstein's "theory of relativity," and what are the discoveries which are accepted as verification of these conclusions?  
Webster, Farwell, and Drew, *op. cit.*, pp. 676-690.
25. What is the "Compton Effect"?  
Webster, Farwell, and Drew, *op. cit.*, pp. 660-662.
26. What is the old "corpuscular theory" of light?  
Webster, Farwell, and Drew, *op. cit.*, pp. 650-652.

27. Give a summary of evidence in support of the electron theory touching upon: (a) the existence of molecules; (b) the existence of particles called electrons—units of electricity; (c) the conclusion that radio and light waves are produced by vibrating electrical charges, and that matter is usually associated with electricity; (d) the nuclear theory of the atom; (e) the conclusion that atoms having similar external structure may have dissimilar nuclei; (f) the theory of spontaneous disintegration of atoms; (g) the “quantum” theory that energy is emitted in “quanta”; (h) the reasonableness of “the corpuscular theory” of light; (i) the photoelectric effect; (j) Bohr’s theory. See text.

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## CHAPTER XI

### ORDER AS SEEN BY THE CHEMIST\*

#### Introductory Considerations—A Correlation

**Inanimate Nature as Microcosm.** The astronomer and the geologist deal with man's conception of inanimate nature as environment in its largest possible aspects—the universe as macrocosm. The physicist and the chemist also deal with inanimate nature; but they are dealing with it as a microcosm—as molecules and atoms, protons and electrons. In this chapter our interest centers in the component elements of substances which man must handle, select for his uses, and work with in order that he may live and realize his conscious purposes.

**The Chemical Field of Inquiry.** Chemistry as a science is concerned chiefly with the characteristic *forms of matter*. It aims to know and make known the *elements* which enter into various substances that abound. It undertakes to do this without respect to the several uses to which these elements may be put—simply as knowledge. It also undertakes to find out how these elements are combined, or may be combined, and the conditions in which varying combinations uniformly take place. This is a way of saying that the chemist is in search of the laws of nature governing not only the forms, but also the *changes* that take place in the forms of matter. His search is for premises for thinking in terms of *cause and effect*. When laying a basis for reasoning about matter, the chemist would explain the how and the why

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of combinations of elements, and the how and the why of changes in these combinations.

**Basic Classification of Data of Chemistry.** Inquiries into the constitution of matter lead the chemist to distinguish between mixtures and compounds. A mixture is recognized as a physical combination of different kinds of substances. A compound is recognized as a single substance made up of a chemical combination of different elements. The chemist has to do chiefly with the latter. And his inquiry into *compounds* cannot be carried far before the need for thinking in terms of elements is apparent. Nor can the inquiry into the changing forms of *combinations* be carried far before the need is likewise apparent for thinking of changes in terms of the forces which produce changes, or which account for each compound as it continues to exist without change. *Chemical research* and reasoning from results soon lead to the fact that each element exists in different forms. It is therefore necessary to develop different conceptions of the *structure* of each element. The theory or conclusion now commonly accepted is that each element and combination is made up of *molecules*; that molecules are made up of elemental units of composition called atoms; and that the atoms are the containers of the incalculable energies which manifest themselves in chemical *reactions* and in other ways.

**The Scientific Interest of the Chemist Distinguished from That of the Physicist.** Both chemist and physicist deal with the constitution of matter. The interest of the physicist is to enable him to know and make known the *forces* within the molecule and the atom rather than the form or forms which the element takes; he thinks about forms only to the extent that this is needful to understand the varying *manifestations of energy*. The physicist, like the chemist, is interested in the changes which take place in the forms because, when these changes in forms do take place, energy is manifest. Not only is the physicist interested in the laws of *dynamics*; he is also interested in *statics*—because he regards statics as a condition in which there are forces in balance. This is the way he has of explaining the why of things which are *at rest*. By the physicist, energy is first divided into two main categories—potential and kinetic. *Potential energy*

is energy within an inert substance in which forces are in balance. Potential energy is impounded energy—which may be released at any time. *Kinetic energy* is the energy contained in matter in which forces are not in balance. When conditions are present that disturb the balance, energy which before was potential only now becomes kinetic. The interest of the physicist in energy has led him, as well as the chemist, to inquire into the units of matter that are the containers of energy. Here both meet on common ground. And because of this fact, the artificial barrier between chemistry and physics has been broken down. Both chemists and physicists now realize that the old term “natural philosophy” is significant.

### Historical Development of Science

**What the Greek and Latin Philosophers Taught.** The idea that all matter is a combination of elements is not new. Nearly three thousand years ago, Greek philosophers, especially Democritus and Epicurus, taught that matter is made up of small particles. Our knowledge of their teachings, especially of Epicurus, has come down to us in the beautiful poem of Lucretius (1st century B.C.) called *De Rerum Natura*. According to this poem, matter is not continuous but made up of separate particles called by the name now used—atoms. They were conceived of as indivisible, indestructible, eternal, impenetrable, and in constant motion. The atoms of different substances were then, as now, thought of as being quite different in size, shape, and weight. And substances, it was held, “differ in properties according to the nature, number, and arrangement of the atoms of which they are composed.” The language of Lucretius sounds suspiciously modern. But the Greeks and Romans did not base their theory on systematic experiment. They were keen observers but their conclusions were little more than a shrewd guess. Their speculations, however, had a marked influence on the thought of thinking men for many centuries; in them is found the germ of the modern atomic theory proposed by Dalton about 1803.

**The Elements as Conceived by the Ancient Greeks.** The earliest Greek philosophers taught that matter consisted ulti-

mately of one of four simple substances and their views culminated in the theory of Aristotle (384-322 B. C.): that all substances are composed of the four "simple bodies"—earth, air, fire, and water; that in addition, there are four elementary qualities—moist, dry, hot, and cold; and that in the simple bodies these qualities are confined in pairs. Earth for example, was cold and dry. Aristotle's theory included the conception of "a primitive matter, that is, a *prima materia* which is common to and at the bottom of the four simple bodies." His theory also included, as a corollary, the mutual transformation of the four elements. The twofold conception of primary matter and of transformations exercised an overwhelming influence upon chemical thought throughout the Middle Ages—indeed, down to the time of Boyle (17th century).

**The Views of the Arabians.** The Arabians pushed chemistry into practical fields, adding little to the previous views of the constitution of matter. Geber, the most noted among the Arabians, however, propounded the idea that there are two constituents of metals, an "earthly smoke" and a "watery steam." Condensation of these vapors in the bowels of the earth give rise to sulphur and mercury. The combination of sulphur and mercury results in the formation of metals. The differences between the six metals (known to the ancients) were thought to be due to differences in the relative proportions of sulphur and mercury in them. Geber also taught that metals having common constituents, might be transmuted one into another. The term "sulphur" and "mercury" were used by Geber as hypothetical substances to which ordinary sulphur and mercury probably form the closest approximations. Subsequently, these terms came to mean, respectively, the combustible and the volatile constituents of metals and, by extension, of matter in general. Geber and his successor, the Persian, Rhazes, believed in the possibility of transmutation, and both believed that they had accomplished it.<sup>1</sup>

**Alchemists in the Middle Ages.** In the Middle Ages, particularly in the 13th century, a galaxy of brilliant men busied themselves with science that made little real advance in chem-

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<sup>1</sup> For a résumé of the chemistry of Islam see books and articles by E. J. Holmyard, especially "Chemistry to the Time of Dalton," pp. 15-30.

istry. The possibility of transmutation was very generally believed and the art was practiced by certain adepts. Another "element," viz., salt, was added by Basil Valentine to the traditional list. Although a man bearing this name probably never existed, the concept of an incombustible, non-metallic residue or "element" in matter took root and served to enlarge the field of the elements passed along from the Greeks.

**The Medical Chemists.** Led by the redoubtable and cosmopolitan Paracelsus (1493-1541), in the latter days of alchemy, chemists diverted their attention from elements, atoms, and molecules, and focused it on substances and processes, especially those related to life. His thinking was premised on the notion that the operations which go on in the human body are chemical ones; and that the state of health depends upon the composition of the organs and the juices. Paracelsus enriched medicine with a large number of valuable preparations and gave a tremendous impetus to the higher development of the apothecary's art. The past was flouted and a new group arose called spagyrist who emphasized the sulphur-mercury-salt idea of the constitution of matter.

**The Contribution of Robert Boyle.** The era of this famous man (1627-1691) was one of mental clarification and scientific progress. He successfully combated the Aristotelian theory of the four elements (earth, air, fire, and water) and the spagyric theory of the three principles (sulphur, mercury, and salt). In place of these he advanced the conception of an element that prevailed until our own time. This was of "a substance which cannot be split up into simpler ones." He thought of chemical compounds in terms of elements. Explaining this conception he says: "I mean by elements . . . certain primitive and simple, or perfectly unmingled bodies; which, not being made of any other bodies, or of one another, are the ingredients of which all those . . . perfectly mixt bodies are immediately compounded, and into which they are ultimately resolved."

**From Boyle to Lavoisier.** The period from Boyle to Lavoisier was one of little advance in knowledge of the constitution of matter. Indeed, for over a century the false theory of phlo-

giston was advocated as an explanation of combustion. This theory obscured the ideas of element and compound, and it dominated all fields of chemistry—especially experiment, interpretation and nomenclature. The keen chemists of this period were overshadowed by the vague talkers and writers. Chaos prevailed until Lavoisier (1743-1794) overthrew the false theory of phlogiston and replaced it by a correct interpretation of combustion. But this was not his greatest service. First, he showed the necessity of relying firmly on the results of careful, comprehensive, quantitative experiments. Second, he redefined the term element, made a new list of the elements, and formulated a plan of distinguishing elements from compounds. Third, in conjunction with others, he prepared a system of naming compounds which is in use today, modified and extended somewhat, to be sure, but unchanged fundamentally. Fourth, he showed by experiment the falsity of the ancient and traditional belief in the transformation of matter, e.g., water into earth, lead into gold. Fifth, he placed chemistry on a scientific basis. Thereby, he provided his contemporaries and immediate successors with adequate means of interpreting chemical substances and phenomena by the use of well-defined terms.

**Dalton's Atomic Theory.** Glancing back, we have seen that (1) the atomic theory of the Greeks was based on speculation, and (2) these views prevailed in a vague way up to the time of Boyle (17th century). From the time of Boyle onward more detailed study of the properties of matter by various chemists tended to confirm the idea that matter is really made up of minute particles. Newton even went so far as to say these particles are "solid, massy, hard, impenetrable, movable, and indestructible." This is doubtless the idea that Dalton first had. Through the study of gases Dalton was led, about 1803, to add certain features which permitted experimental investigations of a quantitative nature, and herein lies the fundamental value of his theory, viz., it could be tested by experiment.

The chief points in Dalton's atomic theory are: (1) The pure, simple substances called elements are composed of exceedingly minute particles called atoms. (2) Atoms of the same element are alike in size and weight. (3) Atoms are indivisible, and

molecules (called "compound atoms" by Dalton) are formed by the union of two or more atoms.

Dalton's atomic theory means, in a few words: that matter is composed of atoms which remain undivided throughout chemical reactions; that they combine in characteristic ways to form molecules of one or another known substance; and that we can trace the travels of atoms from one compound to another by the unvarying atomic weight assigned to each element. Dalton's theory was eminently serviceable; it enabled the many who were at work in the field of chemical research to correlate ascertained facts about reactions. In application, Dalton offered his theory as an explanation of certain facts about the mixing of water vapor and air. It came at a favorable time, and within a few years served as an acceptable explanation of two facts about chemical composition, i.e., constant composition and multiple proportions. By constant composition is meant the unvarying proportions of the elements in any given compound. By multiple proportions is meant the multiple proportions existing between the weight of one element and the weight of other elements in a series of compounds. This theory also stimulated the experimental determination of atomic weights, and necessitated a careful consideration of the meaning of the term atom and molecule (or its synonymous term).

**Berzelius, Dumas, Cannizzaro, Mendeleeff.** Dalton's list of atomic weights is sadly lacking in accuracy, but his idea of finding the relative weights of atoms soon appealed to Berzelius, Dumas, and others; and in their hands the tool was more or less successfully used. We cannot follow the varying fortunes of this mathematical utilization of Dalton's idea of atoms through the period from 1803-1858. We merely emphasize the fact that the outcome, thanks to Cannizzaro, was an accepted table of values in 1858-1860. This gave Mendeleeff the mathematical foundation for his great generalization, made about 1869, which was called the periodic classification of the elements. It also gave to the world a reliable medium for expressing the composition of compounds.

**Avogadro, Laurent, Gerhardt, et al.** Dalton did not distinguish clearly between the terms atom and molecule. A few

did, especially Avogadro, and possibly Gay-Lussac. During the period from the proposal of the atomic theory to the announcement of the periodic classification, the terms atom, molecule, atomic weight, and molecular weight were cleared up—particularly by Laurent and Gerhardt, though many others (e.g., Kekule and Frankland) contributed a share. So that from about 1870 on to 1895 chemists were in almost complete agreement about the constitution of matter. Indeed, the adequacy of Dalton's atomic theory led to a sort of scientific complacency from which chemists seemed unwilling to be shaken until they were startled by discoveries in the fields of electro-chemistry, spectroscopy, X-rays, and radium. Moreover, they were suddenly provided with new tools for investigating the constitution of matter, and speedy use was made of them, especially by the younger chemists. Out of these discoveries have come three other conceptions by means of which the vision of all scientists who deal with forms of matter, energy, forces and mechanistic systems, has been widened, and the reaches of scientific imagination and invention have been greatly enlarged. These conceptions bear the names "The Electron Theory," the "Atomic Number" and, most recently, the "Mass Number." These are discussed in Chapter X, entitled "The Newer Physics."

**Summary of Views Up to About 1890.** Without going into details, chemists commonly held rather rigid views regarding the constitution of matter during a period which may be said to end about the year 1890. These views may be condensed as follows:

1. *Elements* are undecomposable substances.
2. *Compounds* consist of elements united by a force called chemical affinity.
3. *Atoms* are the smallest particles of elements.
4. *Atoms of the same element* are alike and have a fixed weight called the atomic weight, which is determined by refined methods of chemical analysis.
5. *Molecules* are composed of two or more atoms and are the *smallest particles of compounds*.
6. *Molecular weights* are (a) theoretically, the sum of the

atomic weights required by the formula of one molecule, and (b) practically, the approximate values found by experiment.

7. *Chemical change* is a combining, separating or transferring of atoms.

8. *The periodic classification* of the elements is substantially correct.

9. *Valence* is the number that expresses the combining or replacing capacity of one atom of an element.

This summary is confessedly brief and compact, but it includes the traditional belief up to 1890.

### Subject Matter Covered by the Older Chemistry

**Inorganic and Organic Substances.** As has been said, chemistry was among the oldest sciences. Historically, it takes place along side of astronomy—although a firm foundation for scientific thinking was not found until comparatively recent times. Notwithstanding the fact that during the last thirty years the theory of the constitution of matter has undergone a revolutionary change—as in the case of physics—practically all of the results of research obtained since the time of Boyle and Dalton are in the nature of permanent contributions. What many have called “the older chemistry” has given to us by far the greater part of our scientific knowledge in the field. The data of chemistry have been variously classified. For our purpose, all chemistry may be said to fall under two general heads—inorganic and organic. By inorganic substances we mean those compounds (with few exceptions) which do not contain the element carbon; whereas, in organic compounds carbon is the characteristic and essential element.

**Classification for Academic Purposes.** However, this classification does not fulfill the requirements of subject matter when used for purposes of practical reflection. The curriculum of a well-equipped college would divide the subject of chemistry into four general groups, viz.: (1) *inorganic*—including the metals, acids, alkalis, and salts; (2) *organic*—including all those compounds which center around carbon; (3) *physical*—which deals with the general or fundamental principles that cover all chemical

systems; and (4) *analytical*—which deals with the economic aspects of chemical reactions and industrial uses. The first two classes of scientific data above mentioned are considered fundamental to an understanding of chemical science. The third (physical chemistry) gives to us the basis for that profession known as chemical engineering. The fourth (analytical chemistry) gives to us the basis in experimentation for the consideration of practical results in terms of net profit or business advantage.

**The Correlation of Chemical Specializations.** Perhaps a more logical correlation of the several specializations in the field of chemistry would be to divide the data of the subject initially into the two major groups (1) pure science and (2) applied science. That called the pure science is the classified information of data obtained and recorded through experimentation and research—knowledge for the sake of knowledge. The applied science would be thought of as information classified and coordinated with a view to practical application to some one or another objective to be achieved through such knowledge. Accepting the last-named general coordinates (pure science and applied science) as subdivisions of the first we would have the systematic or purely scientific aspects of inorganic, organic, physical, and analytical chemistry. And, as divisions of that general aspect called applied science, we would have first the two subdivisions organic and inorganic, and then each of these would be subdivided as physical and analytical.

**Industrial Chemistry.** The practical application of the information developed in each and all of the above-named subdivisions might be included in what is known as industrial chemistry. In other words, in an industry the chemical laboratories might be so subdivided that research would be carried on in each of the several branches indicated, both as pure chemistry and as applied chemistry. The Eastman Kodak Company, for example, is experimenting all of the time in every one of these branches. The same is true of the General Electric Company and many other companies. In the realm of pure science those results which do not suggest any immediate application to the industry are published and have come to be a considerable part of the literature

of chemistry. However, those results which obviously have a special application to the industry, whether obtained by persons employed in research on the pure science side or on the applied science side, are reserved as secret information and guarded for the uses of the concern under whose patronage the laboratory is maintained.

**Systematic and Practical Literature.** There is one other basis of classification that might be thought of as pertaining more largely to the literature of chemistry rather than to the data developed by its practical uses. From the laboratories of scientific institutions as well as those of industrial pursuit are turned out many volumes of highly technical literature—literature that cannot be read or understood by persons not highly trained in the subject. During the last few years, however, a definite interest has been expressed in popularizing the sciences, and agencies have been established with this end in view. We may, therefore, think of the literature of chemistry as of two general classes—systematic and popular. This fact, however, is to be noted: that, not infrequently, it acts to popularize a highly technical subject. The reader comes to see things in unscientific perspective. On the other hand, the student and the specialist are very likely to gain a perspective which makes them incapable of transmitting their ideas and making the information generally educational. It is quite as important, therefore, that the student should have knowledge of the popular literature of the subject as well as be well grounded in the science.

#### QUESTIONNAIRE WITH READING REFERENCES

1. How is "order" exemplified in the constitution of matter?  
L. C. Newell, *College Chemistry* [N. Y.: Heath, 1925], "Introduction," p. 1.  
*Ency. Britannica*, Vol. VI, article "Chemistry."
2. How is the assumed universal tendency toward order exemplified in what is known as chemical reaction?  
G. S. Newth, *A Text-book of Inorganic Chemistry* [London: Longmans, Green, 1894], pp. 1-2.
3. What is meant by a chemical reaction?  
Newell, *op. cit.*, pp. 16-18, 24-26, 225, 234-236.
4. Thinking of the constitution of matter in terms of order, what is the "system" of order that is the subject of inquiry in the specialized field of chemistry?

5. What were the contributions of early scientists—Egyptians, Assyrians, etc.—to knowledge of the elements?

J. C. Brown, *A History of Chemistry* [London: Churchill, 1913], Ch. I, Early workers, pp. 1-14; Ch. II, Early writers, pp. 15-26.

J. M. Stillman, *The Story of Early Chemistry* [N. Y.: Appleton, 1924], Ch. I, Practical chemistry of the ancients, pp. 1-77; Ch. II, Earliest chemical manuscripts, pp. 78-103; Ch. III, Theories of the ancients of matter and its changes, pp. 104-134.

6. What in general is the subject of scientific interest and research of the chemist?

R. P. Williams, *Essentials of Chemistry* [Boston: Ginn, 1910], What chemistry is, p. 1.

S. E. Tillman, *Descriptive General Chemistry* [N. Y.: Wiley, 1915, 4th ed. rev.], pp. 1-2.

J. T. Stoddard, *Introduction to General Chemistry* [N. Y.: Macmillan, 1910], Ch. I, Preliminary discussion, pp. 1-11.

A. A. Noyes and M. S. Sherrill, *An Advanced Course of Instruction in Chemical Principles* [N. Y.: Macmillan, 1922], The field of chemistry, p. 3.

7. How is the scientific interest of the chemist related to the scientific interest of the physicist?

H. N. McCoy and E. M. Terry, *Introduction to General Chemistry* [N. Y.: McGraw-Hill, 1920, 2nd ed.], A knowledge of physics prerequisite for chemistry, p. 1. Williams, *op. cit.*, pp. 2-7.

Watt's *Dictionary of Chemistry* [London: Longmans, Green, 1888, Morley and Muir revision], Vol. I, Chemical and physical properties of bodies, connection between, pp. 730-731.

A. F. Holleman and H. C. Cooper, *Text-book of Inorganic Chemistry* [N. Y.: Wiley, 1921, 6th Eng. ed. rev.], pp. 2-4.

8. How is the interest of each related to the scientific interest of the astronomer and, in general, what is the contribution of each to the present-day cosmology and philosophy?

9. What were the contributions of prescientific philosophy and especially of Greek and Roman philosophy, to the historic development of the science of chemistry?

Brown, *op. cit.*, Ch. III, Greek physicians and philosophers, pp. 27-39; Ch. XIII, Philosophy of the alchemists, pp. 129-134; Ch. XVI, The philosopher's stone, pp. 173-191.

I. Freund, *The Study of Chemical Composition* [Cambridge, England: Univ. Press, 1904], Ch. IX, Ultimate constitution of matter—hypotheses prior to 1800, pp. 226-283.

10. How were the elements conceived of by the ancient Greeks?

I. Masson, *Three Centuries of Chemistry* [London: Ernest Benn, 1925], p. 62.

Brown, *op. cit.*, Ch. III, Greek physicians and philosophers, pp. 27-39.

F. Cajori, *History of Physics* [N. Y.: Macmillan, 1899], pp. 1-13.

Freund, see reference to question above.

Stillman, *op. cit.*, Ch. III, Theories of the ancients of matter and its changes, pp. 104-134.

11. What were the contributions of the Roman, Alexandrian and Byzantine schools?

Brown, *op. cit.*, Ch. IV, Roman, Alexandrian and Byzantine schools, pp. 40-48.

H. E. Roscoe and C. Schorlemmer, *Treatise on Chemistry* [London: Macmillan, 1905], Vol. I, pp. 4-5.

12. What, in general, were the views of the Arabians with respect to the constitution of matter?

Brown, *op. cit.*, Ch. VI, The Pseudo-Geber, pp. 65-71.

Roscoe and Schorlemmer, *op. cit.*, Vol. I, p. 5.

E. J. Holmyard, *Chemistry to the Time of Dalton* [London: Oxford Univ. Press, 1925], pp. 11-30.

13. What was the contribution of the early alchemists and those of the Middle Ages to an understanding of the constitution of matter?

Brown, *op. cit.*, Ch. VIII, Alchemical treatises of the Middle Ages, pp. 80-89; Ch. IX, The alchemists of the twelfth and thirteenth centuries, pp. 90-99; Ch. X, The alchemists of the fourteenth century, pp. 100-107; Ch. XIV, Aims and methods of the alchemists, pp. 135-151; Ch. XV, the symbolism of the alchemists, pp. 152-172.  
Holmyard, *op. cit.*, pp. 31-55.  
Stillman, *op. cit.*, Ch. IV, The early alchemists, pp. 135-183; Ch. V, Chemical knowledge of the Middle Ages, pp. 184-229.

14. What was the contribution of Paracelsus?

Brown, *op. cit.*, Ch. XI, Protest of Paracelsus, pp. 108-117.  
Roscoe and Schorlemmer, *op. cit.*, Vol. I, pp. 9-11.  
Holmyard, *op. cit.*, pp. 46-48.  
Freund, *op. cit.*, pp. 258, 259.  
A. E. Waite, *Hermetic and Alchemical Writings of Paracelsus* [N. Y.: Theosophical Pub. Co., 1894].

15. What were the contributions of the Iatro-chemists?

Brown, *op. cit.*, Ch. XVII, The Iatro-chemists, (1) Basil Valentine to Oswald Croll, pp. 192-203; Ch. XVIII, The Iatro-chemists, (2) John Rudolph Glauber to Nicholas Lemery, pp. 204-214; Ch. XIX, The Iatro-chemists, (3) Georgius Agricola and the Metallurgists, pp. 215-223.  
Holmyard, *op. cit.*, pp. 45-56.

16. What was the contribution of the Phlogistonists?

Brown, *op. cit.*, Ch. XX, The Phlogistonists, (1) Johann Joachim Becher to Hermann Boerhaave, pp. 224-237; Ch. XXI, The Phlogistonists, (2) Johann Juncker to Pierre Joseph Macquer, pp. 238-250.  
Roscoe and Schorlemmer, *op. cit.*, Vol. I, pp. 13-15.  
Holmyard, *op. cit.*, pp. 56-62.  
Stillman, *op. cit.*, Ch. XI, The eighteenth century—rise and fall of the Phlogiston theory, pp. 424-460.  
Freund, *op. cit.*, Ch. I, Theories of combustion, pp. 31-57.

17. What was the contribution of medieval chemists—especially of the group called “spagyrist”?

Masson, *op. cit.*, Ch. VII, The Growth of Phlogiston, XVII-XVIII centuries, pp. 100-108.

18. Coming to the modern period what was the contribution of Robert Boyle and the other anti-Phlogistonists?

Masson, *op. cit.*, Ch. V, “The father of chemistry”: Robert Boyle, pp. 57-78.  
Brown, *op. cit.*, Ch. XXII, The anti-Phlogistonists, (1) Robert Boyle and Robert Hooke, pp. 251-262; Ch. XXIII, The anti-Phlogistonists, (2) John Mayow and Stephen Hales, pp. 263-274.  
Roscoe and Schorlemmer, *op. cit.*, Vol. I, pp. 11-13.  
Holmyard, *op. cit.*, pp. 63-78.

19. What, in general, was the situation after Boyle and before Lavoisier?

Brown, *op. cit.*, Ch. XXIV, The Quantitative period, (1) The Phlogistonists—Dr. Wm. Cullen to the Honourable Henry Cavendish, pp. 275-283; Ch. XXV, The Quantitative period, (2) The Phlogistonists—Joseph Priestley to Richard Kirwan, pp. 284-292.  
Roscoe and Schorlemmer, *op. cit.*, Vol. I, pp. 15-26.  
Holmyard, *op. cit.*, pp. 79-101.

20. What was the contribution of Lavoisier and the latter-day anti-Phlogistonists?

Brown, *op. cit.*, Ch. XXVI, The Quantitative period, (3) The anti-Phlogistonists—Antoine Laurent Lavoisier, pp. 293-302; Ch. XXVII, The Quantitative period, (4) The anti-Phlogistonists—Guyton de Morveau to Louis Nicolas Vauquelin, pp. 303-312.  
T. E. Thorpe, *Essays in Historical Chemistry* [London: Macmillan, 1923], Ch. V, James Watt, pp. 98-122; Ch. VI, Antoine Laurent Lavoisier, pp. 123-148.  
Roscoe and Schorlemmer, *op. cit.*, Vol. I, pp. 26-34.  
Holmyard, *op. cit.*, pp. 102-110.  
Freund, *op. cit.*, Ch. I, Theories of combustion, pp. 31-57; Ch. II, Lavoisier and the law of conservation of mass, pp. 58-75.  
Stillman, *op. cit.*, Ch. XIV, Lavoisier and the chemical revolution, pp. 511-539.

21. What were the main contributions of Dalton to the modern (atomic) theory of the constitution of matter?

R. M. Caven, *The Foundations of Chemical Theory* [London: Blackie, 1921], p. 9.  
 Brown, *op. cit.*, Ch. XVIII, The Quantitative period, (5) The atomic theory—Carl Friederich Wenzel to John Dalton, pp. 313-323.  
 Holmyard, *op. cit.*, pp. 111-125.  
 Freund, *op. cit.*, Ch. VI, Dalton and the law of multiple ratios, pp. 152-170; Ch. X, Dalton and the atomic hypothesis, pp. 284-300.

22. How did Berzelius, Dumas, Cannizzaro, Mendeleeff and others of this period supplement the work of Dalton?

Roscoe and Schorlemmer, *op. cit.*, Vol. I, pp. 35-40.  
 Thorpe, *op. cit.*, Ch. X, Friedrich Wohler, pp. 294-317; Ch. XII, Hermann Kopp, pp. 364-422.  
 Freund, *op. cit.*, Ch. XIII, Cannizzaro and the application of Avogadro's hypothesis to the determination of molecular weights, pp. 330-360; Ch. XVI, Mendeleeff and the periodic law, pp. 454-505; Ch. XVIII, Berzelius and Isomerism, pp. 545-592.

23. To whom is due the credit for clearly distinguishing between the atom and the molecule?

Caven, *op. cit.*, pp. 3-4.  
 Freund, *op. cit.*, pp. 340-343; Ch. XI, Gay-Lussac and the law of the combining volumes of gases, pp. 301-316.

24. Give a summary of views held by chemists as of, or about, the year 1890 in relation to: (a) the nature of the *elements*; (b) the nature of compounds; (c) the nature of *atoms* as expressed in terms of likeness and fixity of atomic weight; (d) the composition of *molecules* and their relation to compounds; (e) *molecular weight*; (f) the nature of chemical change; (g) the periodic classification of elements; (h) the *valency* of atoms.

25. What in general was the subject matter and subdivisions of "the older chemistry"?

26. How is "organic" distinguished from "inorganic" chemistry?

*Ency. Britannica*, Vol. VI, article "Chemistry."  
 Holleman and Cooper, *op. cit.*, see outline of contents.  
 Newell, *op. cit.*, pp. 1, 44.  
 C. Moureu, *Fundamental Principles of Organic Chemistry* [London: Bell and Sons, 1921, Braunholtz trans.], p. 1.  
 J. F. Norris and K. L. Mark, *Laboratory Exercises in Inorganic Chemistry* [N. Y.: McGraw-Hill, 1922], see outline of contents.

27. What is meant by "physical" chemistry?

J. L. R. Morgan, *The Elements of Physical Chemistry* [N. Y.: Wiley, 1899], Ch. I, Introductory remarks, pp. 1-9.  
 H. J. H. Fenton, *Physical Chemistry for Schools* [Cambridge, England: Univ. Press, 1916], see outline of contents.  
 W. C. M. Lewis, *A System of Physical Chemistry* [N. Y.: Longmans, Green, 1916, Ramsay, ed.], see Preface and outline of contents.  
 F. B. Finter, *An Introduction to Physical Chemistry* [N. Y.: Longmans, Green, 1926], p. xiv.

28. What is meant by "analytical" chemistry?

W. C. Blasdale, *Principles of Quantitative Analysis* [N. Y.: Van Nostrand, 1917], p. 1.  
 W. C. Morgan, *Qualitative Analysis* [N. Y.: Macmillan, 1920].

29. What is the meaning of "pure" as distinguished from "applied" chemistry?

30. What in general has been the development of "industrial" chemistry?  
G. F. Hood and J. A. Carpenter, *Text-book of Practical Chemistry* [London: Churchill, 1921], see outline of contents.
31. What is the basis for the distinction made between "systematic" and "practical" contributions to the literature of the science of chemistry?
32. What is a chemical equation? Discuss as a combination of symbols used to describe a conception of order.  
Newell, *op. cit.*, pp. 17-18, 24, 146-151, 193-195, 221-223.
33. What is meant by chemical equilibrium? Discuss in terms of fundamental characteristics.  
Newell, *op. cit.*, Ch. XII, Chemical equilibrium, pp. 243-276.
34. What is the distinguishing characteristic of formulae representing the chemist's conception of the order existing in organic substance—differentiating this from the combination of symbols used to describe the order existing in inorganic substance?  
J. F. Norris, *Organic Chemistry* [N. Y.: McGraw-Hill, 1922], pp. 18-20, 24-27.

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## CHAPTER XII

### THE NEWER CHEMISTRY \*

**Older Propositions Abandoned.** Out of the wide range of experiments and observations, carried on and recorded by workers in closely related fields of scientific inquiry for the last two decades, has come a conception of the constitution of matter quite in advance of that held up to about 1900. Several of the premises fundamental to reasoning from the time of Dalton down to a comparatively recent date have been abandoned because the advanced thinking of today could not proceed from the older notion that atoms are simple, ultimate, undecomposable and rigid, and that all atoms of the same element are alike in size and weight. The remarkable strides in chemistry and physics, as well as in invention, during the last three decades are based on categories of classification of data and constructive reasoning which negative, or at least profoundly modify, the older postulates. That is to say, instead of assuming that atoms are simple particles without characteristic structure, the present-day conception is that they have a structure just as characteristic of the constituent units of inanimate substances as cells are characteristic of units of different forms of animate matter—atomic structures so complex that they stagger the imagination. Instead of thinking of atoms as ultimate, they are conceived of as relative—determined by conditions; instead of being undecomposable, it is found that some are decomposing unceasingly and others can be broken up into constituents; and, therefore, instead of atoms of the same element (so far as the elements have been isolated by the chemist) being always alike in size and weight, they are variable in these respects. Each of these latter conclusions has been reached scientifically after a long series of confirming experiments conducted by many collaborators in the several related fields of research.

**The Fundamental Conception.** The negative aspect of the newer conception of the constitution of matter is that the atom

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\* By Professor Lyman C. Newell (see note at the head of Chapter XI).

is no longer considered a unit particle of a molecule. The positive aspect is that the atom is now thought of as a unit structure characteristic of an element—each element having a characteristic atomic structure, just as each species in animate nature, when studied microscopically, is found to have a characteristic germ cell and characteristic tissue cells. Following the analogy a little further: just as in the biological sciences, the substance of which all cells and all organisms are composed (protoplasm) is known to have elements in common (as nitrogen, oxygen, hydrogen, calcium, etc.), so chemists and physicists now think of atoms as having common constituents, viz., protons and electrons; but when thinking of atoms structurally, these common constituents are reckoned with as occurring in a characteristically different arrangement and proportion in each elemental substance. Structurally also, the mechanism of each atom is assumed to resemble each other atom in these respects: (a) each atom has a nucleus; (b) the nucleus of each atom is surrounded by other structures (external to the nucleus); (c) each part of the atom as a whole is so related to every other part that together these parts constitute an active atomic mechanism or system. This conception is fundamental because, as has been said, it is necessary to think about the varying manifestations of energy with which the physicist and chemist have to deal. Thus, for purposes of present-day thinking, the atom is postulated as a sub-microscopic structure which serves as the constituent unit of the material universe in which energy plays the major rôle, and which, as a part of the natural order, is subject to and controlled by discoverable natural laws.

**The Atom as Structure.** Starting with this fundamental conception of the natural order, when thinking in terms of atoms, chemists and physicists are now generally agreed on these points:

1. *All protons are alike* wherever found and in whatever combination.
2. *All electrons are alike*—differences in elements being due to differences in the combination and mechanistic arrangement of the electrons around the protons.
3. *While all electrons are alike*, they may exist in the atom under differing conditions distinguished in science as “free” and “bound.”

4. The *nucleus* of each atom contains all the protons and all the "bound" electrons comprehended by the structure as a whole.

5. The part of the atomic system that surrounds and is external to the nucleus contains the associated "free" electrons.

**Significance of Relations of Protons to Electrons.** All thinking about atoms in terms of relations of protons to electrons is premised on the assumption that in each typical or normal atomic system the following is true:

1. The number of protons in excess of electrons within the nucleus of an electrically neutral atom is equal to the number of electrons in the part of the mechanism that is external to the nucleus, and their number (called *the atomic number* of the element) is the same as the excess positive nucleus charge, because each proton bears a unit positive charge and each electron a unit negative one.

2. This *characteristic number* beginning with 1 for hydrogen and increasing by one unit for each element up to 92 for uranium is called the atomic number of the atom (or of the element).

3. The atomic number of an element may be the same and yet its *atomic mass* may be different because the number of protons in the nucleus may be different in two cases, and yet this number may exceed the number of nuclear electrons by the same amount.

4. Atoms having the same atomic number but a different atomic mass are called *isotopes*, and they occupy the same position in the periodic table of the elements, because they have not, as yet, been successfully separated by chemical means.

5. A chemical element may be composed of a given number of one kind of atom and its "isotope" may be composed of another number—this resulting in "*atomic weights*" which are in some cases not integers.

6. The atomic number of all the isotopes of a given element is the same but the atomic mass of each isotope differs from that of any other.

**Use of This Conception When Attempting to Understand the Behavior of Atoms.** Dealing more concretely with an atom (lithium for instance), in terms of this general conception of the structure of the atom and of the characteristics which distinguish

each kind—the number of protons and the number of electrons within the nucleus may vary (as stated in paragraphs 3 to 6 above). That is to say, a lithium atom may be one in which there are 6 or 7 protons and 3 or 4 electrons, respectively, within the nucleus; but in either case there are 3 free electrons outside the nucleus. Such an assumption is necessary in order to understand differences in the behavior of different lithium atoms. But, in developing a hypothesis by which the behavior of atoms may be accounted for, chemists and physicists have come to adopt somewhat different conceptions. We may therefore begin by stating their fundamental agreements.

**Fundamental Agreements with Respect to the Behavior of Atoms.** Each working independently, chemists and physicists have developed theories by which they are able to think about such manifestations as magnetism, electricity, radioactivity on the one hand, and changes in physical properties and chemical conduct on the other. They agree in these essentials:

1. Protons are conceived of as "*positively charged*."
2. Electrons are conceived of as "*negatively charged*."
3. As long as the protons and electrons of an atom remain equal, the energies contained within the atom as a system are in balance and the atom, therefore, is electrically "*neutral*."
4. The "outermost" electrons (external to the nucleus) are the ones capable of transference, or of sharing in *chemical change*—and are therefore called the "valence electrons."
5. When one or more of the valence electrons (those capable of producing chemical change) is lost, the atom becomes "positively" charged—in other words the neutral atom loses a negative charge.
6. Ordinary *chemical and physical properties* are determined by the number and arrangement of the electrons which are external to the nucleus.
7. Phenomena of *radioactivity* are the result of the expulsion of an electron or an alpha particle from the nucleus of the atom.

**The Lewis-Langmuir Theory and the Bohr Theory.** We come now to the two leading electron theories of the structure of matter: the Lewis-Langmuir theory, which, in the past, has been

quite widely accepted and used by chemists, and the Bohr theory, which has found much favor with physicists. Neither of these has proved entirely satisfactory, though each may be said to have its advantages. According to the Lewis-Langmuir theory, the free electrons (i.e., those exterior to the nucleus) are arranged in a series of concentric, more or less stable shells. The Bohr theory postulates the movement of the electrons in orbits instead of being located on or between concentric shells. The Bohr theory is enlarged on by Professor Kent in Chapter X and, therefore, need not be stated here. The Lewis-Langmuir theory is discussed below.

**Illustration of Points of Agreement.** First let us illustrate the points noted above, on which both theories are in agreement, as far as is necessary to explain atomic numbers and valency. For this purpose atoms of hydrogen, helium and lithium are taken. Both theories, when applied to these atoms, agree in the following particulars:

1. The hydrogen atom is the simplest, consisting of one proton (the only one in the nucleus) and one exterior electron; the *atomic number* of hydrogen, therefore, is 1.

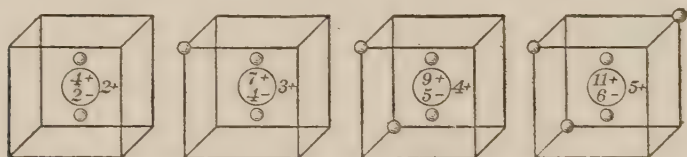


Figure 45. Atomic Structure of Helium, Lithium, Beryllium, and Boron, according to Lewis-Langmuir

2. Next, in this group, is the helium atom which consists of (a) a nucleus containing four protons and two electrons, and (b) two exterior electrons. Hence, the *atomic number* of helium is 2. This arrangement is very stable and corresponds to the inert nature of helium.

3. The lithium atom (excluding the variants of its "isotopes") has a nucleus consisting of (a) seven protons and four electrons and (b) three outer electrons. Hence, the *atomic number* of lithium is 3. Of these outer electrons, two are assumed to be nearer the nucleus than the other one, that is, only one is on or

moves in the "outermost" shell. This is assumed to be so because: (a) the *valence* of lithium is 1; and (b) a neutral lithium atom, when passing from the atomic to the ionic state, becomes a positive ion, i.e., it loses one electron.

**Application of the Concentric Shell Conception by the Chemist.** With this application before us we may proceed. According to the Lewis-Langmuir theory, the exterior electrons in a given atom are more or less stationary, either occupying fixed positions about the nucleus or vibrating about certain fixed positions. As a result, the exterior electrons distribute themselves through and between or over the surface of the shells, these having the nucleus as a common center. Each concentric shell is conceived of as divided into cells or compartments of equal area, i.e., into spaces reserved, so to speak, for the electrons, and from which other electrons may be excluded, or at least limited to a small number.

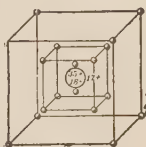


Figure 46. The Chlorine Atom—after Lewis-Langmuir

The maximum number of exterior electrons in the shells that constitute the atomic mechanism is 92—as in the case of uranium.

**Positions of Electrons Represented Geometrically.** Using this conception, the positions of electrons may be represented geometrically by assuming that the electrons occupy definite positions. In certain diagrams the cube is used. The positions as postulated when dealing with certain elements are shown in Figure 45. Lithium, for example, is assumed to have three free protons (not shown) in the nucleus and three exterior electrons. Two of the electrons are shown in shell I; and hence one is left for shell II, so the valence electron is put on one angle of the cube. It should be recalled in this connection that lithium has the valence 1. In chemical changes lithium readily loses one electron. Similarly beryllium, boron, etc., have two, three, etc., electrons on the angles, up to eight for neon.

**The Elements Fluorine and Neon Specifically Considered.** Two elements in this set may be specifically considered. An atom of fluorine is visualized as having nine free protons in the nucleus and nine exterior electrons—two in shell I and seven in shell II. Hence, seven electrons may be shown on the cube. Fluorine can

gain one electron readily, i.e., it has the valence 1. Theoretically, it can lose seven electrons and hence may have the valence 7. In this relation it may be recalled that fluorine is in Group VII of the periodic classification. We may contrast with fluorine the element neon. This has ten free protons and ten exterior electrons—two electrons in shell I and eight in shell II. Hence, an electron may be shown at each angle of the cube. Neon forms no compounds, i.e., its valence is 0, or, in other words, it neither loses nor



Figure 47. Fluorine and Neon Atoms, according to Lewis-Langmuir

gains electrons. Hence, the symmetrical arrangement of the exterior electrons in neon is exceedingly stable.

**Valence Electrons.** If we were to continue with the remaining elements, we should find similar relations, i.e., a periodic recurrence of elements with valence electrons from one to seven, or stable arrangements of eight electrons in the outermost shell. As previously stated, many of the properties of an element, according to the Lewis-Langmuir theory, depend on the number and arrangement of the external electrons, or, more definitely, on the electrons in the outer layer—the so-called valence electrons. Properties also depend on the ease with which given atoms lose, gain, or share electrons. Atoms tend to become more stable, i.e., to lose, gain, or share electrons until a stable arrangement is obtained, e.g., the double or paired arrangement represented by helium, the octet, or eight-group, shown by neon and argon.

**How Chemical Combinations Come About.** As has been said, chemical combinations may be regarded as the transferring or sharing of electrons in the attempt of atoms, so to speak, to form stable pairs or octets. Let us take some examples :

1. In forming sodium fluoride, an atom of sodium transfers one valence electron to an atom of fluorine. The sodium atom, having lost an exterior electron, becomes positive, because one free

proton of the nucleus is now unbalanced. The fluorine atom, having gained an electron, becomes negative because it has one external electron in excess of the number needed to balance the free protons. Hence, the two atoms, being oppositely charged, are held together by the electrical field of force (sometimes called the electro-static attraction).

2. When two atoms of fluorine unite to form a molecule, they share, or hold in common, a pair of electrons in such a way that two octets are completed. Each atom of fluorine has seven external electrons, and in a molecule of fluorine there are fourteen electrons (of the double octet arrangement) being shared by the two atoms.

3. When two atoms of oxygen unite with one atom of carbon to form one molecule of carbon dioxide they share, or hold in common, four pairs of electrons (two pairs on the bases common to both cubes) in such a way that three octets are completed (Figure 48).

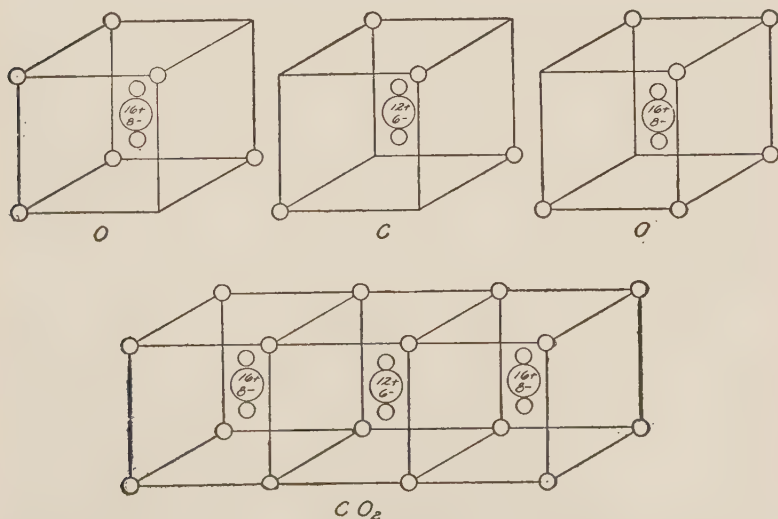


Figure 48. Formation of Carbon Dioxide,  $\text{CO}_2$ , according to the Lewis-Langmuir theory

**New Determinants of What Elements Are.** We may now ask, what is an element? As has been said, we can no longer say

it is an undecomposable, "one-kind" substance. Other criteria must be used. In the case of the elements whose X-ray characteristic spectra (page 163) have been observed, we can say an element is a substance characterized by a series of definite spectra. It is true that elements are also characterized by series of definite spectra composed of longer wave lengths, many of which are in the visible part of the spectrum. Another definition is—an element is a substance whose atoms have the same excess positive nuclear charge. This latter definition is merely another way of saying that an element is a substance all of whose atomic systems have the same atomic number.

The first method of testing the claim of a substance for a place among the elements, i.e., comparison of its spectra, has proved effective and fruitful, especially in the case of helium, radium, the rare atmospheric gases and the so-called rare earth metals. The usual spectroscopic methods have been supplemented, within the last few years, by X-ray spectra which are particularly well adapted to solid elements. This method was used quite recently in the discovery of the elements hafnium and illinium.

**Definitions by International Committee.** The use of the term "element" has been taken up by the International Committee on Chemical Elements, appointed by the International Union of Pure and Applied Chemistry. The report of the International Union for 1923 contains the following statements:

*"Atomic Number.* A chemical element is defined by its atomic number. This number represents the excess of positive over negative charges in the constitution of the atomic nucleus; theoretically, the atomic number represents also the number of electrons which rotate round the central positive nucleus of the atom. Each atomic number also represents the place occupied by the element in the (new) Mendeleeff table. Various methods have been suggested to determine the atomic numbers. The most important of these consists in deducing them from wave lengths of the high frequency spectra first found by Moseley.

*“Elements (simple and complex). Isotopes.* If the above definition is accepted, each chemical element may be simple or complex, according as its atoms are or are not all of equal mass. In the latter case, the element consists of as many isotopes as its atoms have different masses. A complex element is a mixture of isotopes.

*“Notation.* The elements, simple or complex, are represented by the ordinary symbols. To indicate any particular isotope, its atomic mass is written as an index to the right of the symbol representing the mixture. Thus,  $\text{Cl}^{35}$  indicates the isotope of chlorine having an atomic mass, 35. This number represents the relative mass of its atom, the atom of oxygen (a simple element) being taken as 16.”

### Atomic Weights, Atomic Numbers and Mass Numbers

**Isotopes.** Reference has already been made to isotopes, i.e., elements having identical chemical properties, but differing in the two properties, atomic weight and radioactivity. Thus, the atomic weight of ordinary lead is 207.2 whereas lead from radioactive sources is 206.08.

Isotope means, literally, “equal (or the same) place,” and the term is applied to elements which occupy the same place in the new periodic arrangement of the elements; it is also given to elements which have the same atomic number. It should also be noted that apart from radioactivity, the essential point in which isotopes differ is atomic weight.

**Aston’s Table of Isotopic Elements.** Aston’s works on isotopes shows that several non-radioactive elements are isotopic—at least eighteen, probably more. A list of some non-radioactive isotopic elements is given in the table on page 202.

Isotopism may be explained in terms of protons and electrons. Consider lithium as an example. If we regard the respective atomic nuclei as containing 6 protons and 3 electrons, and 7 protons and 4 electrons, then the apparent nuclear charge will be the same (3); that is, the chemical properties of the atoms will be the same though they are of unequal mass.

## ISOTOPIC ELEMENTS

Elements	International Atomic Weight	Number of Isotopes	Atomic Weights of Isotopes
Lithium.....	6.94	2	7, 6
Boron.....	10.9	2	11, 10
Neon.....	20.2	2	20, 22
Magnesium.....	24.32	3	24, 25, 26
Silicon.....	28.3	2	28, 29, 30
Chlorine.....	35.46	2	35, 37
Argon.....	39.88	2	40, 36
Bromine.....	79.92	2	79, 81

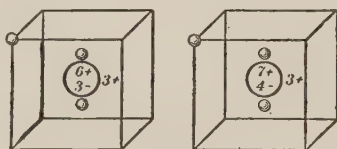


Figure 49. Isotopes of Lithium—after Lewis-Langmuir

**Atomic Numbers.** Each element has a serial number called the atomic number, i.e., the number of the position it occupies in a table arranged according to increasing atomic weights (with some exceptions—see 2 just below). Atomic numbers start with hydrogen, 1, and end with uranium, 92. In the accompanying table the elements are arranged in the same general way as in a periodic table, but in the order of their atomic numbers. Several points should be noted:

1. The general arrangement into groups and periods is not changed. The division into families is omitted.

2. The three pairs of elements anomalously located by their atomic weights are now in the correct order, that is, (a) argon, atomic number 18, precedes potassium, atomic number 19; (b) cobalt, 27, precedes nickel, 28; and (c) tellurium, 52, precedes iodine, 53.

3. The rare earth elements have atomic numbers, but are placed below the table to avoid confusion.

**How Atomic Numbers Are Found.** Light and X-rays are similar. Both affect a photographic plate. The essential difference is in the wave lengths, X-ray waves being very much shorter.

## ARRANGEMENT OF THE ELEMENTS BY ATOMIC NUMBERS

PERIOD	GROUP 0	GROUP I	GROUP II	GROUP III	GROUP IV	GROUP V	GROUP VI	GROUP VII	GROUP VIII
1	2 Helium <sup>1</sup>	3 Lithium	4 Beryllium	5 Boron	6 Carbon	7 Nitrogen	8 Oxygen	9 Fluorine	
2	10 Neon	11 Sodium	12 Magnesium	13 Aluminium	14 Silicon	15 Phosphorus	16 Sulphur	17 Chlorine	
3	18 Argon	19 Potassium	20 Calcium	21 Scandium	22 Titanium	23 Vanadium	24 Chromium	25 Manganese	26 Iron 27 Cobalt 28 Nickel
4	36 Krypton	29 Copper	30 Zinc	31 Gallium	32 Germanium	33 Arsenic	34 Selenium	35 Bromine	
		37 Rubidium	38 Strontium	39 Yttrium	40 Zirconium	41 Columbium	42 Molybdenum	43 Massium	44 Ruthenium 45 Rhodium 46 Palladium
		47 Silver	48 Cadmium	49 Indium	50 Tin	51 Antimony	52 Tellurium	53 Iodine	
5	54 Xenon	55 Cesium 79 Gold	56 Barium 80 Mercury	57 Lanthanum 81 Thallium	58 Cerium <sup>2</sup> 82 Lead	73 Tantalum 83 Bismuth	74 Tungsten 84 Polonium	75 Rhenium 85 —	76 Osmium 77 Iridium 78 Platinum
6	86 Radon	87 —	88 Radium	89 Actinium	90 Thorium	91 Protactinium	92 Uranium		

<sup>1</sup> Hydrogen (1) has no tabular position.<sup>2</sup> Elements between Cerium and Tantalum are 59 Praseodymium, 60 Neodymium, 61 Itrium, 62 Samarium, 63 Europium, 64 Gadolinium, 65 Terbium, 66 Dysprosium, 67 Holmium, 68 Erbium, 69 Thulium, 70 Ytterbium, 71 Lutetium, 72 Hafnium (Celtium).

Figure 50. Table of Atomic Numbers

Visible light, in passing through a glass prism, is spread out into a band of colors called a spectrum. A spectrum is also produced by letting light fall upon a diffraction grating, i.e., a plane surface of glass or metal on which is ruled an enormous number of fine, parallel lines, the lines being separated by distances of the order of the wave length of light.

Diffraction gratings cannot be ruled fine enough for X-ray spectra. But it was discovered in 1912 that an ordinary crystal, such as rock salt, can be used to produce X-ray spectra, because the atoms are arranged in successive rows and layers so close together that they actually form a grating of the fineness adapted to X-rays.

When a high-voltage electric current is passed through a vacuum tube, rays called cathode rays (i.e., streams of electrons) are given off at the cathode. If the cathode rays strike a solid, metallic target (called the anticathode), part of their energy is transformed into X-rays which emerge from the tube. These X-rays, in passing through a slit and falling upon the crystal, produce the X-ray spectra (alluded to above) which may be photographed. A given element yields a characteristic X-ray spectrum.

The facts, substantially as stated above, were discovered and first utilized by the gifted young English physicist, Moseley, who was killed at Gallipoli in 1915—a deplorable loss to science!

When the wave lengths of the strongest lines in the X-ray spectra of elements are measured, the wave lengths of these lines decrease regularly as the atomic weights increase.

If the elements are arranged in the order of these decreasing wave lengths, they follow the order in the periodic classification. Each element is assigned a number, according to its position in the series, thereby giving a succession of whole numbers from 1 (for hydrogen) to 92 (for uranium). These numbers are the atomic numbers.

The atomic number of an element, which is based on energy relations, is more fundamental than its atomic weight, which is based on the mass of the atom. It appears from many observations that the atomic numbers are a comprehensive expression of the properties of elements. Hence, a more exact statement of

the old periodic law would be: *The properties of the elements are a periodic function of their atomic numbers.*

**Retrospect and Prospect.** It is clear from the pages immediately preceding that chemists' views of the constitution of matter are radically different from those of a few decades ago. There is much yet to be uncovered, e.g., the nature and relation of positive electricity, the electronic system of an atom, undiscovered elements, and crystal structure in a comprehensive sense. The chemist has good tools for his future work, and, no doubt his problems will be solved as fast in the future as during the recent years.

**Practical Application of the Results of Chemical Research.** Academic and hypothetical as many of the theories of the chemist may seem to be, it is of interest to note to what discoveries of practical value to the world they have led. Even to list them would transgress the limits of this brief statement. Among those that have contributed to the welfare of mankind the following may be mentioned: The discovery of radium centered attention on the electrical nature of matter. Radium compounds are being used to cure certain skin diseases and other troubles not too deep-seated. The interest in "rays" aroused by the study of radium led directly to applications of this concept to problems widely separated, and resulted in the improvement of X-ray apparatus, especially the large bulbs for X-ray machines, and the use of X-rays in studying metals. One outcome of this application is the detection of cracks and holes in large blocks before the work of machining begins, thus saving much money and forestalling accidents from fractures. The work of Moseley stimulated the search for missing elements, and several have been found—hafnium, illinium, and masurium. The discoveries about electrons have led to interest in minute particles, and encouraged workers in this "unseen" field, resulting in an enlargement of the field of chemistry from colloid particles to sub-atomic ones. Along the way have come discoveries of practical uses of rare elements—molybdenum, selenium, silicon, tungsten—in electro-chemistry, metallurgy, and odd uses. The work on radium started a new interest in energy. One outcome of this study is the application of

atomic hydrogen in producing an intensely hot flame which may replace other sources of intense heat.

### QUESTIONNAIRE WITH READING REFERENCES

1. What conclusions of "the older chemistry" have now been abandoned as untrue? (Refer back to the summary of propositions or conclusions accepted by chemists and physicists as a basis for reasoning about the constitution of matter before the electron theory was propounded—set forth on page 192 of the foregoing chapter.  
B. Harrow, *Romance of the Atom* [N. Y.: Boni and Liveright, 1927], pp. 27-33, 41-45.  
W. F. F. Shearcroft, *Story of the Atom* [London: Ernest Benn, 1925], pp. 25-35.  
I. Masson, *Three Centuries of Chemistry* [N. Y.: Macmillan, 1926], pp. 147-150.  
R. M. Caven, *Foundations of Chemical Theory* [London: Blackie, 1926], pp. 1-17.
2. Instead of the belief held about 1890 that atoms were simple and without characteristic structure, what is the present-day conception?  
E. N. da C. Andrade, *The Atom* [London: Ernest Benn, 1927], pp. 47-48.  
Harrow, *op. cit.*, pp. 74-80.  
Shearcroft, *op. cit.*, pp. 61-64.  
Masson, *op. cit.*, pp. 142-144.  
Caven, *op. cit.*, pp. 93-117.
3. Instead of the belief held about 1890 that atoms were ultimate (unchanged by conditions) what is now held?  
Andrade, *op. cit.*, pp. 9-10, 45-46.
4. Instead of the belief held about 1890 that atoms were undecomposable what is now assumed to be true of them?  
Andrade, *op. cit.*, pp. 65-67.  
J. A. Cranston, *The Structure of Matter* [N. Y.: Van Nostrand, 1925], p. 29.
5. Give a biological analogy of the present-day concept of the relation of atoms to compounds, i.e., compare with the biological conception of the relation of specialized cells to tissue.
6. Analyzed in terms of constituent parts and mechanistic arrangements of parts, in what respects does the structure of the atom as now conceived resemble the structure of the cell organism?
7. What are the fundamentals on which chemists and physicists now agree with respect to the mechanism of the atom?  
L. C. Newell, *College Chemistry* [N. Y.: Heath, 1925], pp. 603-604.
8. What is the significance of the relation of electrons and protons as now conceived by chemists and physicists when considered in relation to: (a) the atomic number of each element; (b) the characteristic number; (c) the atomic mass; (d) atoms having the same number but of different mass; (e) variations in form of atoms and fractional atomic weights; (f) identity of the atomic number of all the isotopes of a given element and the fact that the mass of each differs from all others?  
Harrow, *op. cit.*, pp. 27-87.  
Newell, *op. cit.*, pp. 435-440, 601.

9. What is the value of the electron theory when applied to an understanding of the behavior of atoms?  
Newell, *op. cit.*, p. 607.
10. Give list of seven conclusions with respect to atoms, electrons, and protons—fundamental conceptions that have enabled chemist and physicist better to understand such manifestations as magnetism, electricity, radioactivity, chemical activity, and the properties of matter.
11. What is meant by the phrase “protons are positively charged”?  
Shearcroft, *op. cit.*, pp. 61-62.  
Masson, *op. cit.*, p. 177.
12. What is meant by the phrase “electrons are negatively charged”?  
Andrade, *op. cit.*, pp. 31-34.  
Harrow, *op. cit.*, pp. 49-53.
13. What is assumed to be the circumstance in which an atom is “electrically neutral”?  
Andrade, *op. cit.*, pp. 46-47.  
Shearcroft, *op. cit.*, p. 63.
14. What is assumed to be the circumstance in which an atom is “positively charged”?  
Andrade, *op. cit.*, pp. 34-35.
15. According to the electron theory, what electrons in an atom are the ones that are assumed to be transferred or brought into different relation when there is a chemical reaction?  
Harrow, *op. cit.*, p. 103.
16. What determines the ordinary chemical and physical properties of a substance?  
Newell, *op. cit.*, pp. 440 (§487), 604 (No. 11).
17. In event of a chemical reaction, what is the accompanying electrical effect?  
Newell, *op. cit.*, pp. 221, 223, 226-228, 607.
18. What is the cause of radioactivity?  
Andrade, *op. cit.*, p. 72.  
Harrow, *op. cit.*, pp. 65-67, 79-80.  
Shearcroft, *op. cit.*, pp. 41-58.
19. What is the Lewis-Langmuir application of the electron theory of the constitution of matter?  
Harrow, *op. cit.*, pp. 102-123.  
Shearcroft, *op. cit.*, pp. 64-66.
20. What are the points of agreement between the Bohr application and the Lewis-Langmuir application of the electron theory?  
Masson, *op. cit.*, p. 165.
21. How has the concentric shell conception of the chemist been applied to an understanding of atomic structure?  
Newell, *op. cit.*, pp. 604-607.  
Masson, *op. cit.*, p. 165.

22. Illustrate the Lewis-Langmuir application by reference to the assumed atomic structure of fluorine and neon.  
Harrow, *op. cit.*, pp. 114-116.
23. Upon what does the stability or instability of an element depend?  
Harrow, *op. cit.*, pp. 110-113.
24. Describe how chemical changes are assumed to come about. Illustrate with reference to the formation of sodium fluoride (or sodium chloride).  
Harrow, *op. cit.*, pp. 116-120.
25. What are some of the newer spectroscopic and spectrographic procedures for determining the nature of the elements and for discovering elements not before known to exist?  
Newell, *op. cit.*, pp. 439-440.  
Caven, *op. cit.*, pp. 101-102.  
Shearcroft, *op. cit.*, pp. 73-75.  
Andrade, *op. cit.*, pp. 56-67.
26. What are the derivation and present significance of the word "isotope"?  
Cranston, *op. cit.*, p. 61.  
Harrow, *op. cit.*, pp. 80-83.  
Shearcroft, *op. cit.*, pp. 67-72.  
Andrade, *op. cit.*, p. 50.
27. What are some of the points to be noted when considering atomic numbers?  
Cranston, *op. cit.*, pp. 46-58.  
Shearcroft, *op. cit.*, pp. 73-75.  
Harrow, *op. cit.*, pp. 84-85, 103, 106-107, 109-110.
28. What may be said of the relative value to society of the contribution of the scientist who adds to the perspective in which man sees his environment—who discovers a new element (such as radium), or a condition which causes a kind of chemical change that releases energy (as the pressure necessary to cause Diesel gas to explode), and of the contribution of some one who adds to man's physical equipment (by invention or by organizing a company to exploit radium or manufacture Diesel engines)?

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## CHAPTER XIII

### COLLOID SCIENCE—CONDITIONS PRECEDENT TO LIFE \*

#### States of Matter

**Different Aspects in Which Matter May Be Studied.** As is set forth in Chapter IV, matter as such is one of the main categories used when thinking about that which is objective to the mind. Analyzed into constituents, the material world is conceived of as made up of parts or particles. This is very general. More exactly, the parts or particles are made up of elements; elements are made up of molecules; molecules are made up of atoms; and atoms are made up of protons and electrons (positively and negatively charged constituent particles). Combinations of elements of different kinds in the same molecule are called compounds. Aggregations of particles of different kinds are called mixtures. Matter, when thought about in terms of mechanisms, constitutes systems—natural or artificial. Among the natural systems are those designated as atomic, molecular, planetary, solar, and sidereal. Turning from elements, compounds, mixtures and mechanisms, we may think of matter as existent in different states. When analyzed in terms of “states,” we think of solids (crystalline and amorphous), gases, liquids, and colloids. It is one of these states of matter (the last) which is the subject of scientific inquiry by the colloid specialist. The colloid specialist is usually regarded as a chemist; and the extensive literature on the subject is catalogued as “colloid chemistry.” It is really a separate and fundamental study, in the same sense as is astronomy, geology, or biology—for it makes use of many common chemical, physical, and biological laws for purposes of inquiry, experimentation, and interpretation as applied to a distinct field. Colloid science is a

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body of knowledge resulting from study of one of the most common, yet the least understood, states of matter—study which promises to contribute as much to an understanding of man's environment as any to which human intelligence has turned.<sup>1</sup>

**Difficulty in Defining the Borderland between Chemistry and Physics.** As knowledge gained in scientific research is more highly developed, broad and basic relationships become evident. We have difficulty today in defining the boundaries between physics and chemistry—as we do also between these two sciences and biology or geology. *Physical-chemical methodology* is necessary for many of the investigations constantly being undertaken in all chemical, physical, and allied fields. We are beginning to understand that common laws govern the chemical deportment of substances and of the complicated physical systems—whether these are living or non-living. As the colloidal state is so closely related to life processes, the subject of colloid science is of great interest to workers in the *bio*-sciences and the medical profession. Many industrial processes use colloidal materials, and depend for success on a knowledge of colloid science.

### Colloid Science as a Specialization

**Importance of the Study of the Colloid State of Matter.** The study of the colloid state of matter reveals many remarkable relationships and throws much light on problems in every field of inquiry. We believe today that all the phenomena of life are related to reactions that occur in matter in colloidal condition. The complex compounds of all living matter are in colloidal condition; the life cycle from beginning to end in every species, whether of plant or animal, is an ever-changing sequence of colloidal phenomena. True, many other factors enter; but, that living matter is in colloidal state, and that life processes are coincident with changes that take place in the colloids that constitute the life stream are facts not to be ignored.

**What Is Meant by the Colloid State of Matter.** Some years ago, Ostwald, a famous German chemist, called the colloid

<sup>1</sup> Because of limitations of space nothing is included on the subject of the solids, gases, and liquids as such; they are only incidentally treated.

state the "World of Neglected Dimensions," but today the vast and ever-expanding domain of colloid chemistry is a subject of intensive study. It is convenient to speak of "colloids," but such substances are not members of an isolated or peculiar group. We believe that any kind of matter may be obtained in the colloid state. Svedberg (a prominent colloid chemist) says: "Colloid chemistry is not like electro-chemistry, photo-chemistry, thermo-chemistry, optics, electricity, etc.—the science of a certain group of phenomena; it is the science of a certain group of material systems—the science of systems of a certain structure." Beginning with the conception that we are dealing with a system that differs from all others—a system made up of any kind of matter in such state that it can be combined in solution or suspension—we may leave the more exact definition of the colloid to be developed later.

**The Work of Thomas Graham.** Among the early contributions to this science was the discovery of the Brownian movement—described in Chapter X. Later observers have studied this motion and the Brownian movement has been observed in all cases when matter in a fine state of subdivision is suspended in a mobile medium. This discovery of the Scotch botanist became of great importance, and has led to many valuable contributions in colloid chemistry. In 1861, Thomas Graham published a paper dealing with "Liquid Diffusion Applied to Analysis," and in 1864, reported the results of his investigations on the deportment of silicic acid. He found that certain substances, like sugar, typical salts, and alcohol, diffuse very rapidly in water; but gums, albumen, starch, and gelatine move slowly in the same medium. This latter class of substances is usually non-crystalline, and, due to their amorphous character, Graham called them "colloids," from the Greek word meaning glue. Graham used a glass jar closed at one end with parchment or some other suitable porous membrane. This device was immersed in water and partially filled with a solution of the substance to be investigated. Soluble crystalline materials in true solution passed through the membrane, but colloidal substances like albumen, starch, and gelatine remained in the cell. Such an apparatus

is called a dialyzer, and this method of dealing with colloids is called dialysis.

**Our Modern Views Contrasted with the Views of Graham.** Graham thought that this process of dialysis would largely differentiate the two classes of substances, crystalloid and colloid. We know today that this distinction is not true. But, nevertheless, his discoveries laid the foundation for much that is scientifically sound. Paal found that sodium chloride is a typical colloid in benzene, while von Weimarn, during the last twenty years, has produced many substances in both colloidal and crystalloidal condition. Kahlenberg has recently shown that crystalline substances may be separated from one another if suitable membranes and solutions are used in the dialysis. We have, therefore, abandoned Graham's original definition, and speak of the colloid state of matter as one of structure and not of kind of material. The degree of subdivision determines whether the material is in the colloid state.

**Technical Terms.** The general name of dispersoids has been given to colloids because of the great degree of subdivision of colloid materials. When discussing dispersoids two technical terms are used, which should here be explained, viz., "the internal" or "dispersed phase," and "the dispersion medium" or the "external phase." By the word "dispersed," attention is directed to the finely divided mass, and because these particles are suspended in a medium, they are called the *internal* phase. For like reason, the medium which holds these fine particles in suspension is known as the *external* phase.

### The Central Idea of Colloid Theory

**The Colloid Particle—Micellae.** Colloid theory has been developed on the basis of particles which are aggregates of molecules or ions (i.e., of atoms or groups of atoms which carry either a positive or negative electrical charge). These groups have been named "micellae" (meaning crumblike) to distinguish them from other particles of matter. Colloid science is largely concerned with particles of a size many times larger than molecules.

Molecules are so small that our highest power microscopes fail to reveal their presence; but when a colloidal suspension is exposed to a beam of light in a dark room the path of the beam is illuminated. This is due to the scattering effect of the light on the dispersed phase, and is known as the Tyndall effect. This is one way to distinguish between true solutions and colloidal dispersions. If we examine some river water, muddy because of recent rains, we find that a large part of the suspended material gradually settles out, but another portion seems to remain in indefinite suspension. These smaller particles are in colloidal suspension. A true colloidal dispersion shows the Tyndall effect and the Brownian movement. Because of this movement, sedimentation is indefinitely delayed.

**Dimensions of the Colloid Particle.** Colloid science deals with the properties and behavior of matter in very fine states of division. We cannot impose exact limits to this colloid realm, but,

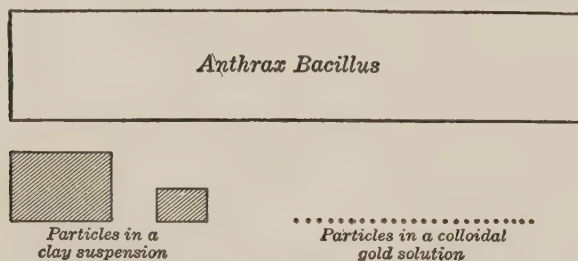


Figure 51. The Relative Size of Colloid Particles. The size of the anthrax bacillus is about  $1/3,600$  of an inch. (From Black and Conant.)

in general, this territory ranges from the lower limit of microscopic visibility to the upper limit of molecular dimensions. The micron designated by the Greek letter  $\mu$  ( $\mu$ ), and the millimicron designated by the Roman letter  $Em$  and the Greek letter  $m\mu$  ( $m\mu$ ) (old notation  $\mu\mu$ ), are used in measuring these minute bodies. The micron equals  $0.001$  of a millimeter; the millimicron,  $0.000001$  of a millimeter. The particles that have dimensions between  $100\ m\mu$  and  $1\ \mu\mu$  are the ones that exhibit typical colloidal deportment. Those particles which are larger or smaller in their behavior, tend to depart from the type.

**The Ultramicroscope—An Instrument for Study of Particles.** English microscopists about 1850 introduced the method of dark background illumination. In 1905, Zsigmondy and Siedentopf devised a slit microscope known as the ultramicroscope. The colloid suspension is examined in a dark room and a converging beam of intense light enters at a right angle to the line of vision. The light is reflected from the colloid particle and aggregates approaching molecular dimensions are revealed as points of light *without apparent diameter*. The use of the ultramicroscope has made possible the solution of many problems in colloid science. Particle size has been determined for many dispersoids. Zsigmondy has found that the smallest particles of colloid gold which can be individually determined have diameters of about  $5\text{ m}\mu$  (five millionths of a millimeter). Alexander states that such a particle magnified 1,000,000 times would be about  $\frac{1}{4}$  inch in diameter, while, in comparison, a human red blood corpuscle would be about 25 feet in diameter, and a hydrogen molecule would be a barely visible speck. As some bacteria are of the same order of dimensions as colloid particles, pathologists have used the ultramicroscope with advantage in the examination of ultramicroscopic organisms.

## The Physics of Colloid Studies

**Changes in Physical Properties as the Particle Reaches Colloidal Dimensions.** Bancroft has defined the subject as the chemistry of grains, drops, films, filaments, and bubbles, because at least one dimension of these systems is of colloidal magnitude. As the particles diminish in size the effect of gravity is greatly lessened, the influence of electric charges is increased, and properties due to surface tension become more important.

**Effect of an Electric Current on Substances in Colloidal Suspension.** If we pass an electric current through a colloidal suspension, the colloid will migrate to one of the electrodes. This is cataphoresis and shows that the particle is electrically charged. Colloid gold is negatively charged, while colloidal hydrated iron oxide is positively charged. Some colloids, however, like starch and protein, show very faint electrical charges. The velocity of

migration is somewhat less rapid than the electrical migration of ions (electrically charged atoms or groups of atoms), but this might be expected because of the size and complexity of the micellae.

**Increase of Surface Due to Subdivision.** If we subdivide a substance until it reaches the dimensions of the micella we will find that the area of the surface is enormously increased. A cube one centimeter on the edge has a total surface of six square centimeters. If it is subdivided so that the new cubes are 0.1 mm on the edge, there would be 1,000,000 new cubes, and the surface would be increased to 600 square centimeters. If this subdivision could be continued until the cubes were 0.001  $m\mu$  on the edge there would be 1 nonillion ( $10^{30}$ ) cubes, and the total surface would be 6 square kilometers, equivalent to 1,482.6 acres, or 2  $1\frac{1}{3}$  square miles. Even these minute cubes are 1,000 times the theoretical size of the electron.

**Adsorption a Very Important Property of Colloid Systems.** With large increases of surface, changes in the distribution and concentration of matter at the surface of colloid particles become extremely important. This modification of concentration at a surface promoted by surface forces is called adsorption. The phenomena of adsorption is perhaps the most important property characterizing colloidal systems. This power of adsorption in favorable conditions is a factor of great importance in many applications of the science—especially in biology—as explaining the phenomena of growth.

**Adsorption Is Highly Selective.** The condensation of gases or vapors upon the surface of solids is an excellent illustration of this action. Adsorption is selective. Varying amounts of gas are adsorbed depending upon the conditions of temperature and pressure, the composition and physical form of the solid, and the kind of gas. Charcoal has long been utilized for adsorption of gases and use was made of this property in the gas masks developed during the World War. Special charcoals were prepared for this purpose and “activated” by a steam treatment at  $950^{\circ}$ . Extensive research has shown that the shape of the pores and

quality of the surface are determining factors as well as the number and dimensions of the openings.

When a water dispersion of sodium silicate is treated with acids of suitable concentration silica gel results. After proper drying, the material will adsorb large amounts of gases. Recently, Holmes has studied the preparation of such gels and by special methods of preparation has greatly increased the number of capillary spaces. These gels adsorb large quantities of vapors. Both charcoal and silica gels have important technical applications.

**Some Illustrations of Adsorption.** When a liquid is adsorbed by a solid, a liquid film is formed, and the liquid wets the solid. When a liquid is placed in contact with a solid in the presence of air, wetting does not take place unless the liquid is adsorbed more strongly than the air. The reader has probably noticed the fact that water wets glass but mercury does not. Water may be removed from gasoline by passing it through a sieve with very fine mesh. Wet canvas will leak when touched, because the air spaces are disturbed and water enters. Adsorption of solutions by the colloidal material of the soil is an important factor in soil fertility. The basic principles of lubrication are involved in this phase of adsorption. Charcoal has been used for decolorizing solutions since 1791. As the adsorption is selective many interesting applications have been made. Chemical reactions may result, due to adsorption.

### Where Chemistry and Physics Meet

**The Effect of Substances Called "Catalysts" on the Velocity of Physical Movement and Chemical Reactions.** Small amounts of certain substances greatly influence the velocity of many chemical reactions. Such substances are called catalysts, from the Greek word meaning decomposition. While the amounts of the materials transformed remain unchanged, the time required to complete the reaction may be increased (negative catalyst), or it may be greatly diminished (positive catalyst). Some one has compared the action of these bodies to the effect of oil on the moving parts of a machine. Catalysis is a contact effect, and increased concentration on the surface of a solid will

increase the reaction velocity. The catalytic effect is not wholly dependent on this factor. The specific nature of the substance is important, and, in certain instances, the size of the pores seems to control the kind of catalytic activity. As many of these questions are as yet unsettled, we will briefly review some of the important technical applications of catalysis.

**Illustrations of the Industrial Use of Catalysts.** Sabatier (an eminent French chemist) discovered that hydrogen will unite with certain carbon compounds in the presence of finely divided nickel. Liquid edible oils are transformed into solid compounds, and this "hardening" of oils has grown into an important industry.

Wood alcohol, or methanol, was formerly obtained as one of the products when wood was distilled in the absence of air. Very recently, this alcohol has been synthesized very cheaply and in large quantities by a new method. Wood alcohol is produced when the gases carbon monoxide and hydrogen are highly compressed and allowed to react in the presence of a special catalyst. Zinc oxide is said to be the important component of the catalyst.

Ammonia is made when hydrogen and nitrogen are passed over a catalyst, largely composed of iron, and containing small amounts of other materials. Temperature and pressure must be carefully controlled. Nitric acid is an extremely important compound both in peace and war. Ammonia and the oxygen of the air react forming oxides of nitrogen, if the mixture of gases is passed over platinum gauze. When these oxides dissolve in water nitric acid is produced. Both of these reactions were of immense importance to Germany during the World War.

**Adsorption of Ions by the Colloidal Aggregate.** We have learned that most colloidal suspensions carry electrical charges. If the colloid aggregate is suspended in a liquid containing ions, the ions may be adsorbed. This adsorption is selective and the dispersed particles become positively or negatively charged depending upon the nature of the material. The hydrated oxides of iron, chromium and aluminum, certain dyes like Bismarck brown and methyl violet, also albumen and agar-agar, carry positive charges. Negatively charged colloids include sulphides of arsenic and cadmium, dyes like indigo, aniline blue, acid fuchsine and eosine, and certain metalloids like iodine, sulphur, and

selenium. Suspension of gold, silver, and platinum, gum arabic, mastic, and soluble starch also migrate to the anode. This classification holds good for aqueous colloidal suspensions. Billitzer has shown that colloidal platinum has a positive charge in aqueous alcohol.

We have seen that the colloid particles are in constant motion due to bombardment from the molecules of the liquid. This is the Brownian movement. Bodies of the same electrical charge repel each other, therefore the charged colloidal particles resist adhesion upon collision. If this were not the case larger aggregates would be formed until the size of the particles became great enough to produce settling.

**The Effect of Ions in Causing Coagulation.** The addition of electrolytes to colloid suspensions generally causes precipitation. When the particles grow in size until they exceed the magnitudes of the colloid realm, coagulation takes place. If the electrolyte supplies an ion of opposite charge which is strongly adsorbed, the original electric charge will be neutralized. When this isoelectric point is reached, coagulation takes place, and the material is precipitated. Hydrogen and hydroxyl ions are produced by acids and alkalis. As these ions are highly adsorbed, these compounds are very effective in producing coagulation. If the electrolyte is added in excess and very rapidly, coagulation may not take place. This is due to the adsorption of an oppositely charged ion, which causes stabilization of the particle.

The effect of dilute acid upon milk is described by Alexander: "By watching in the ultramicroscope the coagulation of the very dilute milk by dilute acid, the individual particles of the colloid casein may be seen to gather gradually together into groups, whose motion becomes progressively less as their size increases, until they are no longer able to stay afloat and finally coagulate in large grape-like clusters."

**The Effect of "Valence" upon the Coagulative Power of the Ion.** The chemist calls the holding power of the elements "valence." Experiment has shown that, as the valence of ions increases, the coagulative power becomes greater. As aluminum has a valence of three, we would expect its compounds to be excellent coagulation agents. This is found to be the case, and

aluminum sulphate is an efficient agent for the clarification of water. Colloid dispersions are often coagulated when another colloid of opposite charge is added to the suspension.

### Classification of Colloid Systems

**Method of Grouping.** A study of the action of water upon glue shows that swelling takes place with jelly formation. At higher temperatures and greater dilutions, the mass changes from a jelly to a viscous solution. Subsequent evaporation yields a solid that can be again dispersed. Such substances are called *reversible* colloids.

When gold and similar suspensions are coagulated, we cannot easily regain the material in colloid condition. These substances are called *irreversible* colloids. Colloids of the glue type have been named *emulsoids* in reference to their deportment with water, while the other kind of substances have been called *suspensoids*. The emulsoids are *hydrophilic* (friendly to water), or *lyophilic* (friendly to solution), and the suspensoid class is often called *hydrophobic* (water hating), or *lyophobic* (solution hating). The emulsoids form stable systems and are coagulated with difficulty.

**Protective Colloids—Their Use.** When an emulsoid is added to a hydrophobic colloid, coagulation is partially or completely inhibited. Faraday made red gold solutions and protected them with some type of jelly, probably gelatine. It is supposed that the emulsoid forms a shell or envelope about the particle, thus preventing adhesion and agglomeration.

Protective colloids are everywhere in the living organism. Gelatine is used in ice cream to prevent formation of gritty crystals. Milk contains a protective colloid, cow's milk less than woman's, so that cow's milk used for infant feeding is frequently modified to prevent rapid coagulation of casein.<sup>2</sup> Glue will retard the time of setting of plaster of Paris. Many compounds prepared by the pharmacist contain protective colloids, and the photographic emulsion is made with the aid of gelatine.

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<sup>2</sup> Recent work (Palmer) tends to disprove the theory that a protective colloid accounts for the stability of milk and he concludes that coagulation is due to changes in the physical state of the chief colloids in milk.

## The Mechanics of Obtaining Substances in Colloidal Condition

**The More Usual Methods.** It has been shown that the colloid particle, or micella is the important unit of colloid systems. A brief, non-technical discussion of the methods used to obtain the particle will aid in obtaining a clearer understanding of the subject. The more usual methods of preparation can be divided into two general classes: (a) subdivision of the mass into colloid particles (dispersion); (b) association of molecules to form colloid particles (condensation).

*Examples of Class A.* If a mass of glue is dispersed in water, or some nitrocellulose is dispersed in an alcohol-ether mixture, we get an example of a method based upon subdivision of the mass into colloidal aggregates. A colloidal dispersion results when a gum like rosin or mastic is dissolved in alcohol and the solution is poured into another liquid, usually water, in which the material is insoluble. This is a general method for producing suspensions. Mechanical disintegration is sometimes effected by grinding in the "colloid mill" or homogenizer. These machines depend upon the shearing of a liquid film, the disintegration being due to hydraulic forces.

*Examples of Class B.* When an electric arc is formed between wires, the metal is vaporized. If the arc burns under the surface of a suitable liquid, condensation takes place, and a colloid solution results. Many sols are produced by condensation of molecules to form colloidal aggregates. Beautifully colored gold suspensions are readily made by the addition of certain chemical compounds called reducing agents. Suspensions of silver, mercury, and platinum are also easily produced by this method. We have seen that the concentration of ions is an important factor in coagulation. Compounds produced by chemical reactions when few ions are present generally appear as colloidal suspensions.

### Emulsions, Foams, Gels, and Jellies

**Formation of Emulsions.** When one liquid is shaken with another in which it is nearly insoluble, a dispersion results called

an emulsion, but separation into layers soon takes place. Oil and water mixtures are familiar illustrations. The water has a high surface tension and this force always tends to make the surface as small as possible. The liquid drops will coalesce to form one large drop or layer. A third substance, the emulsifying agent, is necessary if we wish stable emulsions. We may have oil drops dispersed in water, or, the unusual type, drops of water dispersed in oil. In any case, the emulsifying agent probably forms a viscous film around the drop to prevent coalescence. Mayonnaise is an emulsion of oil in water with egg albumen as the emulsifying agent. Milk contains drops of butter fat dispersed in water. The formation of stable emulsions is of great importance in pharmacy.

**Formation of Foams.** When oil is dispersed in water to form an emulsion, the larger oil drops may rise to the surface to form a cream. This cream would consist of the drops surrounded by a viscous film, and might contain little free water. If the oil drops are replaced with air, a type of froth would be formed. In order to produce a foam it is necessary to have a decided difference in concentration between the surface layer and the rest of the solution. If a stable foam is desired a surface film of high viscosity is necessary, or another substance must be added which will concentrate in the surface and stabilize the film. True solutions will foam, but colloidal solutions generally give foams of much greater stability. When cream is churned a foam must be produced. The butter fat collects at the surface, and as the foam breaks the particles coalesce and form butter. Modern methods of ore flotation depend upon the production of froths. Air bubbles are produced in the presence of certain oils. These bubbles, covered with a thin film of oil, are surrounded by water. If certain kinds of finely ground ore are present, the valuable portion stabilizes the bubbles, forming a froth, concentrating the values at the surface. This froth can be easily removed leaving the worthless residue in the tank.

Carbon dioxide gas can be produced as a very stable foam. Such a froth will float on burning oil and makes a very effective fire extinguisher. The foam is stabilized by the addition of suitable colloids.

**Formation of Gels.** We have seen that glue and other emulsoids are readily dispersed in water to form sols (*hydrosols*). If alcohol was the dispersing fluid we would speak of an *alcosol*. When coagulation takes place, the colloid particles agglomerate and form a *gel*. When the material sets without visible excess fluid, we have a *jelly*. Just as we have *hydrosols* and *alcosols*, we name the corresponding gel types, *hydrogels* or *alcogels*.

**The Theory of Gel Formation.** When we have a fluid sol, the drops of the dispersed, or inner phase, are distributed throughout the dispersion medium (outside phase). If the fluid is removed by evaporation, or the solution is cooled, the drops of colloidal material may increase in size and come in contact, forming some type of gel structure, with great decrease of fluidity. If the swollen colloid particles touch and coalesce in the form of films, a structure like the cells of a honeycomb results. These cells contain the water or other dispersion medium, thus reversing the original structure of the emulsoid sol. Other conditions may produce adhering threads or rods forming net structures somewhat like a brush pile. The subject of gel structure is not yet fully understood but constant research is being conducted in this field.

Gelatinous precipitates contain adsorbed liquid; they are always viscous; and under suitable conditions they may form jellies. Typical jellies contract, and liquid appears (syneresis). Many jellies lose structure with age.

We are familiar with many types of gels. Gelatinous precipitates are often formed in chemical reactions. Von Weimarn discovered that many inorganic compounds could be obtained in the gel condition if they were formed from solutions of very high concentration. Gelatinous precipitates or true jellies result, depending upon the degree of concentration and the ability of the material to adsorb the solvent (solvation).

**Common Types of Gels and Jellies.** Silica gel is used for the adsorption of gases and liquids. Fruit jellies are produced from fruit juices if certain carbon compounds called pectin are present in sufficient quantity. "Solidified" alcohol is an alcogel, and gelatine jelly is a common food product. It may later be found that nutrient material in the form of gels is transported

from cell to cell in the living tissue. This interesting theory awaits experimental confirmation.

### Gas As the Dispersion Medium

**Aerosols.** When solids or liquids are dispersed in a gas, *fumes, smokes, fogs, mists, or clouds* result. Aerosols are obtained by the same general methods used to produce other disperse systems. Subdivision of the original mass of material, or condensation of the substance from molecular condition will produce dispersions of this type.

Mechanical disintegration produces the dust clouds of the dry, unpaved road, the volcanic dust floating in the atmosphere, the finely divided dusts of the cement plant, the spray of the sea, and the solid or liquid dispersion produced by the bursting shell. Various types of apparatus are used to reduce liquids to finely divided mists. Grinding materials to form very fine dry powders is an expensive operation and offers many mechanical difficulties.

**Formation of Aerosols by Condensation Methods.** Condensation of vapors produces disperse systems of high degrees of dispersion. When a gas is cooled throughout its entire volume and the temperature falls below the dew point, simultaneous condensation takes place. Particles of dust or other substances must be present to act as condensation nuclei. The character of the condensed vapor varies with the conditions of temperature. If water vapor is condensed below  $0^{\circ}$  clouds of ice crystals result, but water, condensed above  $0^{\circ}$  and subsequently cooled below that temperature, deposits ice scales on the adjacent solid surfaces. The deportment of water is typical of many other substances.

Many chemical reactions produce solid products in finely divided condition. The gases, ammonia and hydrogen chloride, unite to form clouds of ammonium chloride (sal ammoniac).

Phosphorus bombs give dense clouds when exploded, and compounds like titanium chloride react with water to form the smoke screens used in the navy, or when sprayed from an airplane form the sky writing of the aerial advertiser.

**Aerosols in Industry.** Various industries produce aerosols of different types depending on particle size. The dispersion medium may be air, or gases produced in the operation of the process. Dusts have the largest particles and settle rapidly in a still atmosphere. Clouds have particles of smaller size and settle in still air. The rate of settling is constant and dependent on the size of the particles. Neither dusts nor clouds diffuse. Smokes have particles small enough to exhibit the Brownian movement, and will diffuse rapidly. The elimination of dusts and fumes is an important industrial problem as many of these are dangerous to health, and smelter fumes will kill vegetation and also cause loss due to the waste of valuable material. Dangerous dust explosions result when grain, coal or other dusts formed from combustible materials become ignited.

Since the control of fumes and dusts is of great importance, Cottrell (an American chemist) invented an apparatus that is very efficient for their removal. The colloid particles receive an electric charge from a charged wire located in the flue. A plate situated near the wire attracts the oppositely charged particles, causing precipitation.

Beyersdorfer suggests that Sodom and Gomorrah were destroyed by a charged mist of petroleum formed in the Caucasus and carried down to these cities. There the particles lost their electrical charge, coalesced and precipitated as petroleum rain which was ignited by lightning. It is of interest to note that these rains occur today.

## The Rôle of the Colloid State in Nature

**Scientific Inferences of Geologist and Mineralogist.** Geological science has recently been enriched by the application of the colloid theory. Colloidal phenomena are constantly taking place where air, land, and water meet. Such surfaces are lake, river and sea bottoms, and the rocks and soils exposed to atmospheric contact.

Many minerals began their history as gels, later to reappear as hardened masses with characteristic rounded form. The mineralogist calls these structures oolitic, mammillary, botryoidal, or spheroidal, and Rogers gives them the general name "colloform."

Such minerals nearly always contain water, and may change with age and varying temperatures to crystalline modifications.

Solutions may diffuse through gels, react and form crystals, or produce the rhythmic banding so familiar in certain agates. The opal is an example of a hardened silica gel. Concretions are often formed and valuable deposits of iron, aluminum and manganese collect as hydrous oxides forming ore beds.

The soluble portions of the rocks eventually reach the ocean. Clays and earths in suspension are transported by river waters and coagulated by electrolytes present in sea water, and the delta at the river's mouth is partially formed by this action. The myriad kinds of sea life build up calcium carbonate, forming shells and coral reefs. Islands rise, and limestone is deposited because of the biochemical colloidal reactions of marine organisms.

**The Soil and Colloid Chemistry.** We are just beginning to realize the importance of the colloid chemistry of the soil. Classical chemistry has not given the answer to many of the problems which await solution.

Soil colloids fall into two classes, the organic remains of plant and animal life, and secondary products of ultramicroscopic dimensions, produced by the decomposition of rocks, mostly complex silicates.

The plasticity of wet soils and the hardness of dry ones are due to soil colloids. The food supply of the plant is obtained from adsorbed soil solutions, and water is stored away, part of which is taken up by plants through the semipermeable membranes of the seed and roots.

**Colloid Chemistry of the Sky.** Particles of dust, water and ice in the upper air give us our daylight. If the light of the sun were not diffused, we would live in a strange and unfamiliar world. Atmospheric moisture in colloidal dispersion gives us clouds and fogs and, when coagulation occurs, forms rain and snow.

The blue sky is the blue of turbid media, the color accented because seen against the "black background of infinite space." The mackerel sky is supposed to be due to the rhythmic banding of atmospheric waves.

The color of the sunset, and the lingering twilight glow are

due to scattering of the sun's rays by dust particles and gas molecules. The volcanic eruption of Krakatoa, in 1883, threw dust in immense quantities high up in the air, and atmospheric currents carried it around the world. Bancroft states: "After sunset, and by virtue of the diffusion of red light by this layer of particles, the whole western sky, even to near the zenith, glared with a lurid red, as though lighted up from some great and distant fire."

The comet's tail is said to be made up of colloid particles, and Arrhenius has suggested that charged dust and smokes travel from the sun to reach the earth.

### Industrial Applications of Colloid Science

**Photography.** If we make a survey of industries based on colloid chemistry, we will find that they represent a large and important group. The problems of photography are colloidal from the production of the sensitized emulsion on the film, through the processes of exposure, development and printing.

**Ceramics.** The properties of clay and clay products are the properties of colloidal materials, and the manufacturer must deal with problems of hydration, dehydration, particle size, the effect of protective colloids, and deflocculating agents. When a brick is "burned," irreversible dehydration occurs, shrinkage is controlled by proper treatment, and it is said that the clays of Egypt need straw, perhaps as a source of tannin, when used for brick making.

**Rubber.** Raw rubber is a colloidal system of great complexity, and the crude juice (latex) contains about 40 per cent of rubber. The globules present exhibit the Brownian movement, and are negatively charged (cataphoresis experiments). Rubber is *hydrophobic*, exhibiting no swelling in water present in the latex, and it is supposed that natural protective agents (proteins) act as emulsifying agents. All of us are familiar with the injurious effect of oil on our automobile tires, showing that rubber swells in certain liquid carbon compounds becoming highly solvated; and raw rubber (crêpe) can be completely dispersed to form our rub-

ber cements. When rubber is treated with sulphur, new properties appear, but little is known of the reasons for these changes.

**Vulcanization.** Vulcanization is supposed to be due to the union of sulphur with the rubber, and subsequent dispersion of the newly formed compound in the mass of uncombined rubber. Rubber loses its properties with age and exposure, and chemists are eagerly searching for the correct answer to these problems. Synthetic rubber has not arrived as a commercial product, and the colloid chemistry of the plant continues to exceed in efficiency the best efforts of our laboratories.

**Leather and the Tanning Industry.** The substances composing the hide are colloidal, and tanning materials are mostly colloids, so this important industry is closely associated with the colloid state. Many operations in the tanning process are not clearly understood, but the industry is rapidly being placed under scientific control. The hair is removed by quicklime, which also removes those cementing materials which hold together the filaments of the skin. The chief constituent of hide is a protein substance called collagen (glue former), which is further prepared for tanning by the action of certain enzymes. The resulting jelly is then exposed to the action of vegetable extracts (tannin), and leather is produced.

We are not prepared to say whether this is a wholly physical operation but, in any case, adsorption is probably important, and coagulation of the positively charged skin fibers and the negatively charged tannin is known to take place. Protective colloids are present, and the size of the tannin particles seems to be an important factor.

**Colloid Chemistry and the Dye Industry.** Dyes aid in giving color to the world, and today we have available a wealth of material mostly made in the chemical factory. Many of the colloidal principles previously discussed are illustrated in dyeing, and the present conflict of divergent theories will eventually cease as continued research reveals the basic principles underlying the industry. Vegetable fibers are colloidal in structure, and often adsorb the dye directly, but some must first adsorb other substances called *mordants* which, in turn, "fix" the dye.

Acid dyes are used for wood and silk but rarely for cotton, a vegetable fiber; while those of another class (the basic dyes) are used for wool and silk directly—they are fixed on cotton by means of tannin. We have noted before that the colloidal dyes are electrically charged, and mutual precipitation may occur, or protective agents may prevent agglomeration. Colloid research has given the world a new fiber, rayon, and application of the principles of this science will continue to enrich this industry.

**Paints.** The manufacture of paints, varnishes and related pigments involves questions of the particle size of pigments, and the preparation of stable suspensions.

**Other Industries.** The manufacture of soap and the explanation of detergent action involve colloidal problems that the soap maker and the laundry must solve successfully. Glasses are supercooled liquids and, if colored, contain dispersed materials, as gold and selenium which produce ruby glass. If crystallization occurs, the glass is injured in quality.

The cement industry is of major importance, and the field of metals and alloys is now being investigated from the standpoint of colloidal chemistry. This discussion could be extended almost indefinitely but enough has been said to show that the colloid in industry is an extensive and important topic.

## Preparation of Foods and Colloid Science

**Chemistry of the Dietary.** A few years ago we heard a great deal about calories and the chemical analysis of foods. While more recent discoveries have taught us something about those somewhat mysterious bodies, the vitamins, we are now just beginning to realize the importance of the physical condition of our foodstuffs. With the exception of a few inorganic compounds, all our foods are in colloidal condition.

**The Kitchen a Colloid Laboratory.** We use yeast to increase the surface of our leavened breads, and hydration or swelling is a common phenomenon of the kitchen. The foodstuffs are broken up in the digestive tract, and the products rebuilt to form the

colloid tissues of the body. Emulsions like mayonnaise are often prepared, while cream and butter afford illustrations of dispersions of fat in water, and water in fat. Extraction of animal juices to make soups, or dehydration of the external tissues (searing) to retain the juices in the meat are familiar operations. Our coffee is settled by egg albumen, and the chemistry of baking is colloid chemistry. Many of our food products depend upon taste, odor and flavor to be palatable. The large size of the colloid particles aids the body by prolonging the formation of simple products produced in digestion, and also masks the nauseating and irritating properties of the decomposition products. The whipping of cream results in the formation of a double emulsion since the original oil in water emulsion must be maintained, and a new dispersion of air in water produced. Space does not admit of further discussion; a fact to be emphasized is that the kitchen is a colloid laboratory, and that our health depends upon an intelligent use of basic colloid principles.

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24. What is a foam—how are foams formed?  
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29. Give illustration of aerosols in nature.  
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PART THREE  
ANIMATE NATURE



## CHAPTER XIV

### APPLICATION OF COLLOID SCIENCE TO BIOLOGY \*

**Conditions Antecedent to Life.** Attention may now be given to the contributions of science to our knowledge of animate nature. Our approach is from the field of specialization considered in the preceding chapter—colloid science. Life is a manifestation of energy in colloid mechanism. The materials needed for life are colloidal. All life processes take place in that kind of a colloid system called a hydrosol. Because of these facts, it follows that life could not have existed before the earth had sufficiently cooled to form water. Until then the conditions were not such as to produce the kind of colloid needed in the vital processes. It is evident, therefore, that colloid science has an important contribution to make to theories of evolution.<sup>1</sup>

**Problems of Biology; Problems of Colloid Science.** When considering the origin and development of living things, many questions are raised. All of them, however, pertain to colloids. The problems of biological science, being problems of colloid science, must be solved in terms of colloid theory. Colloid science is fundamental to the interpretation of biological phenomena. Rapid advances are being made in the development of biological theory; but even the commonest reactions of the living organism are often explained with great difficulty. Many theories of colloidal biochemistry have been advanced that are irreconcilable; final solution must await fuller knowledge of the deportment of colloid systems, the operations of the simplest of which are still in controversy. The properties of such simple systems as colloidal gold and platinum are not yet fully investigated; and when we attempt the study of living substance, protoplasm, we are confronted with complexities which leave the whole subject of organic function unsettled.

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\* By Professor Ralph N. Maxson (see note at head of Chapter XIII).

<sup>1</sup> This paragraph by the editor.

**Inherent Difficulties of Biological Colloid Investigations.**

Biologists have attempted to explain the functional reactions of protoplasm as a chemical result or a result of operation of the laws of physics. The real answer to questions raised about living matter depends on the experimental study of protoplasm as colloid. The living substance of the cell is contained in tiny sealed compartments and attempts to isolate it frequently result in death with profound changes in the properties of the material. This adds to the difficulties encountered; for the cell content exists as unstable and complex fluid systems; and each cell system is surrounded by a wall that acts like a rigid gel. The cell fluids are dispersions in water (hydrosols); the unicellular organisms which live in water receive their food supply from very dilute solutions. On every hand difficulties are met which have not as yet been overcome.

**The Cell the Seat of Electrical Charges.** We have already seen that the micellae of unorganized matter are electrically charged; and all the evidence seems to show that the granules, droplets or sols of the living substance (protoplasm) also carry a charge—while the cell wall (membrane surface) is the seat of an electrical charge of opposite sign. It seems evident that the physical, chemical and biological deportment of living matter is closely related to electrical phenomena. In this, as in all other respects, therefore, it seems that colloid action in living things is very similar to the movements and activities within non-living and inorganic hydrosols.

**The Life Process a Sequence of Complicated Colloid Changes.** The life process is a sequence of ever-changing colloid systems; emulsions form, typical sols appear, or gels are produced according to the constant variations in the biochemistry of the organism. Thus, the further development of knowledge of the life processes themselves depends on the conclusions reached through the painstaking inquiries of the colloid scientist, and one phase of this inquiry must have for its objective a better understanding of selective membranes developed by organisms.

**The Cell Wall a Semipermeable Membrane with Selective Action.** It has been stated that semipermeable membranes allow

substances in true solution to pass through the wall but largely inhibit the diffusion of the colloid particle. Various theories have been advanced to explain this phenomenon and we know that the action is much more complex than a simple sieve effect. The wall of the living cell also acts in this way but, unlike the product of the laboratory, is self-forming and also selective under different conditions. It is able to admit or exclude materials and, when at rest, substances like glucose, the only sugar used by the body, are excluded, but when activity is resumed these same substances pass through the cell wall.

**Colloid Chemical Reactions of the Organism.** The living organism builds up its tissues from the simpler decomposition (cleavage) products obtained from the complex colloid particles digested in the alimentary tract. It is able to cause profound changes in certain fat-like bodies called the lipins and transform carbohydrates, like starches and sugars, building up complex carbon compounds with ease. Moreover, these reactions take place at low temperatures and with great rapidity, although the chemist often has difficulty in producing these substances in the laboratory because as yet we do not understand their chemistry.

**The Enzyme an Important Factor.** In bringing about chemical change, enzymes are an important factor. The colloid scientist believes that the enzymes are necessary in many of the complicated reactions of living matter; they probably form unstable adsorption compounds. After the colloid complex has served its purpose in the life process subsequent decomposition liberates the enzyme which, in turn, forms new compounds—thereby contributing to the tearing-down and upbuilding process on which vital energy and growth depend. This branch of colloid science is still in its infancy.

**The Effect of Ionic Concentration and the Antagonistic Effect of Ions.** Colloid particles have an ability to hold to their surfaces (i.e., to adsorb) other substances, even ions. A given surface may have a preference for certain ions and thus in one case acquire a charge by holding a positive ion, charge and all. Another kind of colloid may choose to acquire a negative ion and charge. The hydrogen ion concentration (a measure of temporary

acidity) and the action of electrolytes are of great interest to the biochemist. Loeb has found that certain marine organisms will live in solutions of sodium chloride (common salt) if a suitable number of calcium ions are present, but in their absence death occurs although the salt solution (sodium chloride) has the same amount of this salt as is present in sea water. This important antagonistic action is also illustrated by the toxic effect of sodium ions. If a frog's heart is perfused by a sodium chloride solution of such concentration that it has the same osmotic pressure as the blood (isotonic), it will cease to beat; but this effect is counteracted by the calcium ion. The concentration of calcium ions needed to neutralize the toxic effect of the sodium ion is about the same as has been found to exist in sea water and the blood of animals. This interesting action of ions has been observed in connection with plant growth and seems to be a well-established biological fact. It has been suggested by Weiser that the reversible permeability of the cell wall is due to varying concentrations of sodium and calcium ions present in solution in certain body fluids.

**Imbibition of Water by Living Tissue.** The colloids of the living organism have the ability to imbibe enormous amounts of water. The quantity of water present is largely determined by the concentration of acids, alkalies and salts. Swelling phenomena are important in the colloid chemistry of growth and great pressures are developed, as is seen when the growing tree splits the rock apart.

Research has shown that the growing tissues of plants contain large amounts of water and that the acid concentration is increased during the period of growth. Healthy living tissue can hold about 80 per cent of water and has a normal state of turgor.

**Causes and the Effect of Acid Accumulation.** The carbon compounds taken in as food are largely eliminated as carbonic acid but when the metabolic equilibrium of the body is disturbed, acetone (a toxic compound) and other bodies result producing abnormal conditions. "Acidosis" is a technical name for diminished alkalinity so it can be seen that the measurement of the temporary acidity (hydrogen ion concentration) is a valuable guide when pathological conditions arise.

Martin Fischer has shown that abnormal secretion of acids causes greatly increased water holding capacity. Abnormal swelling (oedema) occurs when such conditions arise, and nephritis is closely related to acid concentration.

**Reproduction, Growth, and Metabolism as Influenced by Colloidal Reactions.** If we examine the structure of the fertilized egg, we find that certain changes take place no matter whether fertilization was produced sexually or by artificial laboratory methods. Modifications of form occur and part of the cell content appears as threads, assuming a skein-like form and later collecting as two nuclei.<sup>2</sup> Increases in viscosity are noted and the whole operation indicates coagulation—the transformation of a sol to a gel. Growth involves dispersion, coagulation, adsorption and colloidal protection. Imbibition of water is a factor of large importance and the complex colloid systems of the germ cell certainly have a large influence in determining the difference between plants and animals, and the more or less hidden facts of heredity. As Alexander puts it, “from the same soil we may produce a lily or a beet, a turnip and a rose.”

The formation of sols, gels and emulsions accounts in part for the synthetic and destructive reactions constantly taking place both in health and disease. Shrinkage (syneresis) of the gel structures explains the change from the rounded tissues of youth to the shrunken ones of old age. We must look to colloid chemistry for the ultimate explanation of many unsolved problems of evolution, growth, reproduction and the very important chemistry of the ductless glands.

**Relation of Colloid Science to Hygiene and Medicine.** Further development of the sciences of hygiene and medicine is in no small degree dependent on colloid studies. Modern medicine is using the concepts of colloid science to aid in the study of immunity, the healing of wounds, and the complex problems related to secretion and excretion. Chemo-therapy will progress much more rapidly when we are able to predict with greater accuracy the effect of compounds on the colloid systems of the living organism. We cannot expect rapid progress until we replace the “rule of thumb” methods, largely employed in such research, with

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<sup>2</sup> For definition of nucleus and cell physiology see Chapter XVI.

a system of attack based upon the physics and biochemistry of the colloid state.

**The Future of Colloid Science.** After this brief review of results obtained in this important field we can understand why Ostwald wrote, "Colloid chemistry is the promised land of the biological scientist." Unfortunately, we know very little as yet of the actual physics and chemistry of life. But the rapid progress made during the last two or three decades in colloid science augurs well. It promises to illuminate many obscure places in each of the sciences dealing with animals as well as inanimate nature. Not many years ago the subject was considered to be a mere branch of physical chemistry. As before observed, it is more than a branch either of physics or chemistry. It has expanded until it occupies a territory all its own. It is a broad fundamental science dealing with one of the five states of matter. Findlay once called the colloid state "the twilight zone of matter." Due to rapidly increasing knowledge, the result of many and varied researches, the subject can no longer be considered as being in the twilight. It stands forth clearly and distinctly as a new intellectual light. By its radiance many a dark shadow has already been removed from the more largely traveled and better known paths of a world which man has come to be aware of, his physical environment.

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Freundlich, *op. cit.*, pp. 759-768.

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9. Discuss the conflicting effects of negatively and positively charged ions in connection with the chemical change and growth in organisms.

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Heilbrunn, *op. cit.*, pp. 141-142.

10. How does the imbibition of water relate to growth?

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11. Give some illustrations of the effect of acidosis.

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12. Discuss colloid reactions in terms of reproduction, growth and metabolism.

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## CHAPTER XV

### THE BEGINNING OF LIFE \*

**Questions About Life.** The student with an inquisitive mind on first approaching the study of living matter finds himself asking a number of questions that science cannot answer. We can offer only theories of greater or lesser degrees of probability. What is life? How did life first come into existence? How long has there been life on this earth? Does life exist elsewhere in the universe? Has living matter always had the same forms on this earth that are present today? Why do plants and animals stop growing? What is death? Why does death occur? These are some of the questions that occur to the scientific as well as to the unscientific inquirer.

**How Living Matter Differs from the Non-Living.** It is safe to say that no entirely satisfactory definition of life has been formulated. As has been said in Chapter XIV, living matter consists of a collection of chemical substances in a colloid state. This has a more or less definite organization or arrangement. It is probable that it is the arrangement, plus the associated characteristic movements of the minute constituent particles of the colloid that constitute the difference between living and lifeless matter. It is obvious that in an essay dealing with the beginning we must depart from the grosser manifestations of life and death. A frog hopping about is clearly alive. An axe falls and cuts off

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\* Chapter prepared by the editor with the assistance of Doctor Arthur W. Weyssse, Dean of Boston University Graduate School, and Professor of Biology in Boston University, College of Liberal Arts. A.B., 1891; A.M., 1892; Ph.D., 1894 (Harvard Univ.); M.D., 1907 (Univ. of Basel, Switzerland). Author: *An Epitome of Human Histology*, 1898; *A Synoptic Text-book of Zoölogy*, 1904; *Medico-Legal Moral Offences* (translated and enlarged from the French of Thoinot), 1911; numerous papers on research work in Embryology, Anatomy, and Physiology.

Dr. Weyssse is directly responsible for pages 245 to 248, and pages 256 and 257; the other matter is taken from writings on organic evolution, principally from the volume of Professor Macfarlane, Head of the Department of Biology of the University of Pennsylvania, noted on page 248.

his head. The frog is dead. But if we turn him over, divide the skin, and separate the underlying muscles, we find the heart beating as regularly as ever. The heart is not dead; and it may even be removed from the body and still continue to beat. If placed in water containing certain chemicals in right proportions the frog's heart will beat for hours after the body has been decapitated.

**The Chemical Constituents.** Turning now to forms simpler than the animal or even the organ, as we analyze in the chemical laboratory matter that has had life, we find no new chemical *elements* in it that do not exist in lifeless matter. We do find some chemical *compounds* that do not appear in matter that has never had life; but not a few of these compounds have in recent years been produced in the laboratory by synthetic chemists, and undoubtedly more will be synthesized in the future. The name given to the special associations of chemical compounds that constitute living matter is *protoplasm*, as is explained elsewhere.

**Difficulties Experienced in Classification.** All forms of living matter are classified as plants or animals, although it is not always possible to say definitely which; for all consist of protoplasm and some of the simpler forms of life are difficult to classify. Individual plants and animals are called organisms; and so we sometimes call living matter organic, and matter that has never had life, inorganic. Protoplasm consists of chemical compounds in a colloid state; it behaves like a fluid—minute particles being in a state of suspension and in motion. As is explained in the preceding chapter, protoplasm belongs to a class of matter called hydrosols—meaning matter the suspending medium for which is water. Under certain conditions the fluid colloid may become solid, forming what is called a gel, and the hydrosol then becomes a hydrogel. This change takes place when protoplasm dies; and the reverse process of the gel back to a sol then becomes impossible.

### Theories Concerning the Origin of Life

**Spontaneous Generation.** Most of the distinctive chemical compounds found in protoplasm cannot be manufactured by man, nor, so far as we know, can they be produced except by the proto-

plasm itself, i.e., by living matter. The assumption that living matter could arise by natural processes from lifeless matter is called the theory of spontaneous generation. This hypothesis has led to many experiments; and it was not definitely disproved until the latter part of the nineteenth century. We have no reason to believe that under the physical and chemical conditions that exist at present on the earth, living matter can come into existence from lifeless matter; in other words, so far as has been determined all known existing protoplasm has been produced from pre-existing protoplasm. But the science of geology has led to these conclusions: (1) there must have been a time when conditions were unfavorable to life; (2) there must have been a time when there was no water—when matter could not have existed in a colloidal state; (3) there must have been a time when no living thing could have existed on this earth.

**The Star-Dust Theory.** This being true, how then did organic matter arise on this earth? A subject of such speculative human interest has naturally given rise to theories. It has been suggested that life did not originate here but came to the earth from outer space. Matter is constantly falling into the earth from without. May not this matter have brought with it some simpler form of life and this living organic matter finding conditions here favorable to its growth and development have given rise by evolution to all the forms of life that have existed on the earth? There is no reason to believe that any forms of life of which we have knowledge could withstand the intense cold of interstellar space and the great heat generated on striking the atmosphere of the earth. We have no evidence in fact that would support the theory of an origin of life from without and hence it does not appeal to scientists.

**The Special Creation Theory.** Another theory has been suggested by which those who hold it would account for the origin of life. Their assumption is that life had its beginning in some creative process not involving the application of the established laws that govern matter under other circumstances. This is known as the special creation theory. Such a hypothesis naturally would not be attractive to the scientist; for he conceives of the universe as subject to the orderly application of

definite physical and chemical laws some of which he knows, some of which he will know in the future and some of which he may never know.

**Naturalistic Theory.** A fourth theory is more largely favored: that at some time in the history of our earth conditions were such that living matter was formed from lifeless matter by purely natural processes. This theory appeals to the scientist because it is in accord with his experiences in making observations of natural phenomena; but he is not in a position to say what those conditions may have been or why they do not exist today. Science having reached the conclusion that the earth has undergone many changes; that at one time it was an intensely hot, luminous gas; that at successive stages it was a molten globular mass, then formed a crust; and that soon after a crust was formed it was too hot for water to form during a long period—science having reached such a conclusion, the biologist is quite ready to accept the view that life began at a relatively recent date in geological time, and that it developed according to natural laws, when conditions became favorable. This broad conclusion, however, leaves the way open for further investigation and experiment; and a greater accumulation of facts may lead in the future to more definite knowledge.

### Elemental and Primordial Forms<sup>1</sup>

**Protoplasm.** Proceeding from the naturalistic hypothesis, it is obvious that the most primitive forms of living matter were but a first step in a procession of changes which occurred from time to time as conditions became different from what they had been. The most elemental of all of the structures with which the biologist has to deal is found in the arrangement and structure of the kind of hydrosol or plasm in which vital energy is developed and which is common to all organisms. It is by reason of the primordial character of the arrangement of the particles composing the plasm, that it is called *protoplasm*. Each different kind of organism is known to have a characteristic kind of protoplasm.

<sup>1</sup> The material presented under this general head, as far as "When and Where Life Began," has been summarized from J. M. Macfarlane, *The Causes and Course of Organic Evolution*, Macmillan, 1918, and related literature.

However, it is assumed that every kind of protoplasm has such an arrangement of its colloidal particles that it is adapted to the continuous process of taking into itself materials of such molecular composition and complexity that they possess high potentials in energy—which, when broken down, release energy—and which by chemical change produce substances that may be assimilated in upkeep and growth of the substance itself.

**Theories About the Structure of Protoplasm.** The structure of this colloidal state of matter called protoplasm is so minute that it cannot be seen and observed, except in its grosser aspects, even by microscopes of highest power. What its more refined and intimate arrangements are can only be inferred. By reason of the fact that certain characteristic processes are carried on, however, scientists have drawn conclusions which serve as working hypotheses. One theory is that the structure of protoplasm is reticular—forms a very minute mesh or structural network—with submicroscopic spaces through which the various liquids that carry substances in solution or colloidal suspension pass; such a mechanism, it is assumed, would be adapted to the selective processes carried on, the result of which is chemical reactions with electrical charges and discharges and the organization of new compounds; this would also be adapted to the distribution and assimilation of materials needed for the upbuilding and growth of the living substance. Another theory is that protoplasm may take the form of an arrangement of minute globules or particles; and that a functioning organism as a unitary body depends for its vital energies, chemical and mechanical operations on physical laws—such as ionization, polarity, cleavage, surface tension, osmosis, etc. There are other theories, but we need not do more than to restate the hypothesis that the *plasm* itself is the primordial form and structure of living matter; that it is assumed to be adapted to carry on vital processes without any further elaboration or higher development in complexity; and that the different kinds of protoplasm are to be thought of as products of a process of adaptation to conditions that have led to specialization processes associated with the evolution of species.

**Theory That Life Originated in a Primitive Ooze.** The foregoing conclusion, as a matter of scientific deduction, leads to

the philosophical speculation on the part of certain writers that the beginning of life must have been in a primordial, inorganic ooze—which in conditions then favorable, developed increasing complexity with power to reproduce itself, and which had the power further to adapt itself to environment. This is simply another way of saying that protoplasm and organisms which came to constitute typical forms or species were developed by a natural process after the atmosphere and the hydrosphere had been formed in later-day reaches of geological time—after the earth crust had cooled down to a point which made vital substances possible. Support is found for this induction in the scientifically established facts marshalled by many writers who approach the subject of evolution from studies of resemblance between inorganic and organic colloids. Among these we may mention Leduc. And use is made of this hypothesis by biologists—among whom are Macallum, Macfarlane and Bassett.

**The Chemical Garden.** Leduc in his treatise on the mechanism of life points to numerous instances in which the placing of fragments of inorganic substance in a hydrosol results in manifestations of chemical activity, growth, etc., similar to the organic and structural changes of living things. For example, Leduc tells us that chloride of lime—when placed in an inorganic solution, composed of potassium carbonate (76 parts), sodium sulphate (20 parts), and tribasic potassium phosphate (4 parts)—acts in the following manner: “The calcium chloride surrounds itself with an osmotic membrane; water penetrates into the interior of the cell thus formed, and a beautiful transparent spherical cell is the result, the summit of which soon emerges from the shallow liquid—this is a most impressive spectacle of osmotic production, half aquatic, and half aerial, absorbing water and salts by its base, and losing water and volatile products by evaporation from its summit while at the same time it absorbs and dissolves the gases of the atmosphere.” He then makes the further comment on the behavior of this and certain other inorganic colloids: “Like a living being, an osmotic growth absorbs nutriment from the medium in which it grows, and this nutriment it assimilates and organizes.” Various products of

this kind so nearly resemble plants that they are commercially sold as "chemical gardens."

**The Simplest Organism.** Macallum, in a paper read before the Canadian institute, observed that in seeking "to explain the origin of life, we do not require to postulate a highly complex organism such as we can see even with the low power of the microscope, as being the primal parent of all, but rather one which consists of a few molecules only and of such size that it is beyond the limits of vision with the highest powers of the microscope. Such an organism would be the smallest unit of life and it might be supposed that protoplasm arose from aggregation of such units, each more or less differentiated from its fellows, just as the higher or multicellular forms of life have arisen by the aggregation of cells which have differentiated more or less, thus giving rise to differences of function in the different parts."<sup>2</sup> Macfarlane, an outstanding American biologist, makes use of some such conception of primordial plasm in his theory of organic evolution—his assumption being that the basic substance of all living matter is "protoplasmatin," in which vital energy is assumed to have had its beginning. This is premised as a non-nucleated type of cellular structure common to the Acaryota. From the non-nucleated unicells he assumed that higher forms were evolved; from these were developed the unicellular species (the protophyta and protozoa); then followed the multicellular species (the metaphyta and metazoa).

**The Sulphur Bacteria.** Similar inferences have been drawn from the scientifically established fact that certain of the very primitive bacteria still live in the vicinity of hot sulphur and iron springs. It is observed that some of the colorless (or slightly yellow) varieties can live in the dark—as in subterranean places, their supply of energy being obtained from sulphur compounds in hydrosols instead of from sunlight. Fischer thinks of these as possible prototypes—his thought being that free hydrogen must have been generated during volcanic changes in the Archean period.<sup>3</sup> Adverting to this conclusion, Macfarlane says, at certain temperatures (as 250° to 300° C.) hydrogen could unite with

<sup>2</sup> Quoted by Macfarlane, *op. cit.*, p. 39.

<sup>3</sup> *Structures and Functions of Bacteria*, Clarendon Press, 1900, pp. 7, 65-68.

free sulphur or with sulphide salts to form hydrogen sulphide ( $\text{H}_2\text{S}$ ). The bacteria could then "absorb this into their colloid protoplasmic substance, and there oxidize it, setting free the sulphur in the protoplasm as minute yellowish granules visible to the eye. In the act of union of the hydrogen and oxygen, heat energy is evolved. At the present day the earlier stages of the process are started by the liberation of nascent hydrogen gas from decomposing plants." The writer thinks that this accounts for existing

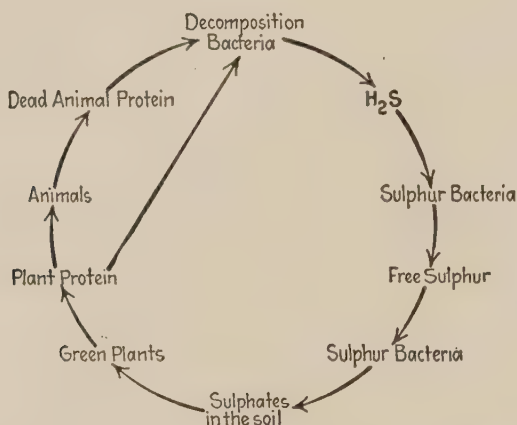


Figure 52. The Sulphur Cycle. (From Thomas.)

sulphur bacteria (like *Beggiatoa*, *Chromatium*, and *Thiothrix*), "surviving types of very ancient forms that originated amid the ceaseless physico-chemical changes of the archæan epoch."<sup>4</sup>

**Nitrogen Bacteria.** Another kind of bacteria assumed to be of very primitive type is an order of beings capable of fixing loose inorganic nitrogenous compounds—even in the dark. With these bacteria persons engaged in agricultural pursuits are quite familiar. They infest the roots of beans, peas, clover, etc.; their activities in fixing nitrogen adding much to the fertility of the soil. Other forms of bacteria might be considered also, such as the rod-shaped species of pink, pink purple, and purple color—mainly found in marshy or brackish expanses of mud flats. Engelmann has proved that they can absorb and utilize infra-rays for the upbuilding of

<sup>4</sup> Macfarlane, *op. cit.*, pp. 40-41.

food molecules.<sup>5</sup> The iron bacteria might also be noted (associated with the formation of bog ore)—iron being an essential in the formation of the given protoplasmic substance on which the chemism of most of the plants depends (chlorophyl). The bacteria which are able to transform inorganic matter into food are assumed to be among the most primitive organisms; those unicells which live on cumulations of organic matter such as the bacilli,



Figure 53. Tubercles with Nitrogen-Fixing Bacteria on the Roots of Red Clover. (From Gruenberg.)

and the larger types of unicells and multicells (plants and animals) are assumed to have followed.

**The Blue Algae.** Among the more highly organized unicells is a group which still lives in the hot-water pools formed by geysers—some forty different kinds having been identified. Setchell (Science N. S., Vol. 17) shows that these thrive in temperatures as high as  $75^{\circ}$  C. (a scalding heat to most organisms), in the Western American Geyser regions—about twenty species growing normally in siliceous and carbonated hot springs. These are thought to have played a considerable part in the later Archean:

<sup>5</sup> Macfarlane, *op. cit.*, p. 41.

geological period in the laying down of silica and carbonate of lime. They are mentioned here as among the evidences which point to primordial types of organisms adapted to carrying on

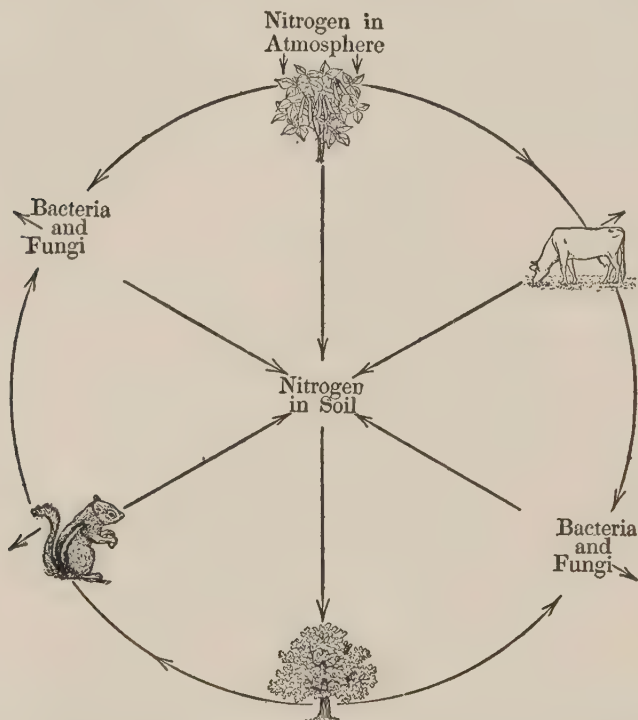


Figure 54. Nitrogen compounds are withdrawn from the soil by plants (represented by the tree). These furnish food for animals (as the squirrel) and also for other plants (as bacteria and fungi). Some of the products of life activity are returned to the soil; other nitrogen compounds are scattered and lost in the air. Nitrogen is returned to the soil by nitrogen-fixing bacteria on the roots of plants of the bean family (represented by the bean plant). Bacterial action in decay brings about a return of nitrogen in the bodies of dead plants and animals. (From Gruenberg.)

vital processes when the atmospheric as well as the water temperature of the earth's surface was high—as it must have been in the Archean and Precambrian ages.

**The Cell as Prototype.** When dealing with forms and types more highly developed than those that are submicroscopic (such as many forms of non-nucleated organisms), we come within a

field in which direct scientific observation is possible. The structure and the functions of organisms that can be directly studied have been repeatedly described. A very large scientific literature has developed in every branch of microscopic morphology, and physiology—including cytology, embryology, ontology, histology, and pathology. As is explained in Chapter XVI, the constituent unit of all organisms is scientifically known to be a discrete mass called a cell. These units vary enormously, in size, shape and structure. The larger animals and plants are composed of countless numbers of these constituent units. But there are many organisms whose entire body consists of a single cell. Many such, the majority in fact, are so small that as individuals they are invisible. Because the least complex of all beings, (and in point of geological time, the oldest) the unicellular species (the protista) may be considered prototypes. Some of the smallest of the unicellular beings are less than  $1/125,000$  of an inch in diameter. We have reason to believe that there may be organisms much smaller than these. In these submicroscopic species, however, all the vital processes are carried on. In fact, as has already been said, it must be assumed as a common characteristic of protoplasm that it is constantly changing in chemical composition; that in connection with these changes the vital process called metabolism takes place; that to this end the cell must receive a supply of substances from without. The substances which serve these ends are known as food.

**Complementary Functions of Different Kinds of Cells and Organisms.** During the ages there were changes—adaptations. The structural characteristics of even the most minute one-cell species were modified according to the surroundings and especially as determined by supply of substances that served as food. Marked differences have already been noted in the sulphur bacteria, the nitrogen bacteria, the iron bacteria, the purple bacteria, etc. The most significant of all the changes in protoplasmic adaptation was that which developed in plants—the green substance called chlorophyl. This has the power to use the energy of the sunlight to link up carbon and water into carbohydrates. Because chlorophyl makes use of the energies of the sun, it has contributed more to the abundance of life than any other substance. It is the most

permanent, persistent and widely distributed kind of living matter. Broadly speaking, it may be said to be fundamental—because on it depends the chemistry of all the green plants on whose cell chemistry the production of most of the substances that serve as animal foods depends. The volume of organic matter is cumulative. The more highly organized plants live on matter previously organized. Animals feed on plants or on previously organized animal products. Protista, plants and animals (as these have evolved throughout geological ages) have been complementary—the success of one depending on the success of the other. The study of these complementary processes is the subject matter of geology.

### When and Where Life Began

**Geological Inference.** If we attempt to fix the time at which life began, we find great diversity of opinion. We must rely chiefly on the geologist and especially on the paleontologist for data on which to base an estimate. During the past quarter of a century there has been a tendency to increase the length of time during which life has probably existed on the earth. Many animals and plants that have existed in the past have been buried by natural processes and transformed into fossils. As we find these remaining in successive layers of the earth's crust we get a picture of life as it occupied the world in past ages—multitudes of plants and animals that once flourished in great numbers have disappeared entirely just as have the mastodon and the great auk within the period of man. As we pass in review the fossils from the most recent to the oldest we find them becoming more and more simple in structure. While estimates vary concerning the time involved, they are all so great as to be almost beyond the comprehension of the human mind. It was formerly believed at one time that life might have been in existence on this earth for about 60,000,000 years. Now the estimates are much greater, and some geologists believe that living matter has existed here for 1,500,000,000 years.

**Speculations as to Place.** Any conclusion drawn concerning the place where life may have first appeared on the earth must

again be in the nature of speculation. With the formation of the atmosphere, the separation of the oceans from the land, the cooling of the heated waters, it is assumed, a time came when protoplasm, as we know it, could exist and the most favorable place would have been in the water. Gradually, it is thought, the sea margins, where the tides rose and fell, became a marginal breeding ground for land species. Ultimately, what before were barren continents became invested with vegetation and these became the feeding grounds for thousands of species of land animals.

Thus, we conceive of life as beginning in matter in the colloidal state—in organic structures of extreme simplicity and strictly in accord with physico-chemical laws. The simplicity of the colloid structure was probably much greater than that of any form of organism we have yet seen; and changes, it is believed, have come about in an orderly manner. These natural laws, as they are called, have been the biological determinants of adaptations; many of the resulting changes may not seem to us to have been useful—but in any event they were natural. Conditions determined the success and failure of myriads of species evolved in accord with nature's plan and nature's laws. In this relation, let the observation be repeated, that while science adheres to a theory of orderly change, in accounting for the many forms of organisms, it cannot do more than record and interpret facts observed. How, when and where life began must be left to philosophic speculation.

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## CHAPTER XVI

### LIFE'S MECHANISMS \*

**The Perspective of the Biologist as Gained from Other Sciences.** In Chapters IV to XIII astronomer, geologist, chemist, and physicist, have dealt with non-living aspects of matter. Chapter XIV deals with the colloid—a state of matter that is common in living as well as in non-living substance. Chapter XV deals with the beginning of life—life as it manifests itself in primitive organisms. Each tells a story of order. Each deals with a different aspect of universal order. Each gives to us a picture of different mechanistic arrangements by which the incalculable potential energies of nature are made kinetic, and by which kinetic energies are brought into balance. The biologist is interested in living matter. But he also must think in terms of inanimate nature. In one sense biology is astronomy—in that life depends on the energy of the sun and on that sidereal order of which the solar system is a part. In another sense biology is geology—in that it pertains to the earth. In still another sense biology is a branch of chemistry—in that it depends on changes brought about in compounds and mixtures in conditions favorable to the release of energy. And in still another sense biology is a branch of physics—in that it deals with mechanics, heat, light, sound, electricity, etc. But biology is something more. The biologist is interested in environment as “an order of things” which makes it possible for living things to exist and carry on.

**Biological Specializations.** The interest and enthusiasm of the biologist centers in a study of different kinds of organisms.

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But in the quest for knowledge about living things, each has been led to make observations and to draw conclusions not made and reasoned about by others. Many biological specializations have been developed; and these have come to be labeled with different names. In the interest of perspective, some of these are here noted. To the orderly arrangement of the observed facts of cell life is given the name *cytology*. Cells combine and form tissues; *histology* is the name given to the science dealing with this aspect of biological science. Tissues combine as organs; and organs are the gross functioning parts of each organism as a whole. The scientific study of form and changes in structure (the results of adaptation of organisms to environment when functioning) is called *morphology*; that of the purely structural aspects of organisms of every kind has come to bear the distinctive name *anatomy*; the study of the functional aspects of organisms has come to bear the distinctive title *physiology*. Introduction of the microscope as an instrument of observation led to a further distinction between *gross anatomy and physiology* and *microscopic anatomy and physiology*. When specialization came to be directed to different organs, this gave rise to corresponding groupings of results, such as: *dermatology*—studies of the anatomy and physiology of the skin; *neurology*—studies of the anatomy and physiology of the nervous system; *osteology*—studies of the anatomy and physiology of the bones; etc. And related to all these are the developed arts in specializations of *hygiene, medicine, surgery, histology, pathology*—differing applications of scientific knowledge to problems of health, and prevention and relief of pathological (abnormal) conditions.

**What Is Life?** Life has been characterized as “the mystery of the universe.” But to the scientist, *life* is no more a mystery than is electricity, heat, light, radioactivity, chemical affinity, gravitation, osmosis, and various other manifestations of energy. Scientifically conceived, life is one of the manifestations of energy. Life can be scientifically studied, as can all other manifestations of energy, in terms of the physical facts by which it comes to be known. Life, like other manifestations of energy, is thought about in terms of the substance in which life inheres, and the mechanism in which and through which it acts. If the biologist

could tell what vital energy is, could define it in any other terms than the distinctiveness of the "life substance" and of "organisms"—the mechanisms through which it is manifest—the whole subject matter of biology would, I presume, be greatly simplified. But it seems impossible, with our present knowledge, to state in more concise terms what life is. Lewes defines life as "a series of definite and effective changes, both in structure and composition, which takes place in the individual without destroying its identity." This is an attempt to define life in terms of mechanism. Spencer defines it as "the continual adjustment of internal relations to external relations"—a statement in terms of the need for adapting the mechanism to conditions favorable to the development of vital force. These, while possibly the most nearly satisfactory definitions so far presented, seem to leave us groping without any definite mental picture. The reason that no concise or comprehensive definition of life (as such) has been formulated is that life is so immensely complex that it evades concise definition; it is so unique that it is impossible to define it by relating it or comparing it to something else.

**Different Views of Life—Vitalists.** When the subject is reasoned about in terms of cause and effect, one group of thinkers, who call themselves *vitalists*, holds that life is due to the presence in living organisms of some "all-controlling, unknown, and unknowable, mystical, hyper-mechanical force." Such a view of life is satisfying only to the reasoning of the dogmatic thinker. It does not prove helpful to the scientist because it closes the mind to observable and verifiable fact when in search for truth; it removes the whole subject of adaptation to environment from the realm of investigation. No biologist makes use of such a working hypothesis—however useful the concept may be as a premise for the philosophical reasoning of an absolutist. There is a tinge of vitalism in the philosophy of a goodly number of those who consider themselves scientific; but to this extent they limit the range of their observations—they inhibit the use of their powers of induction.

**The Mechanistic View.** A far more satisfactory hypothesis or viewpoint for the study of vital phenomena, and one strictly in accord with scientific method, is called the *mechanistic view*.

The viewpoint here taken is that this conception is consistent with the premises and working hypothesis used by the other natural scientists—the only one which is consistent with reasoning about the facts which stare the biologist in the face when he looks at the structure and functioning of organic tissue through a microscope. In other words, the point of view which has proved of greatest advantage for scientific observation is, that life is a manifestation of energy in a peculiar kind of mechanism—"a new kind of world's stuff" which is the physical basis of biological science.

**Nature of Vital Mechanism.** In the preceding chapter it was pointed out that this new organic substance peculiar to the manifestations of energy called life is a kind of matter known to science as *protoplasm*. The view commonly held is that—whereas other manifestations of energy (such as heat, light, electricity) are the product of physical and chemical change in relatively simple forms of matter (inorganic)—the various manifestations of life are, in last analysis, products of physical and chemical changes in highly complex mechanisms that have come to be recognized and distinguished as living matter. Not only is protoplasm complex in molecular arrangement, but it has great instability; and it is almost infinitely variable in its composition. That is, protoplasmic mechanisms exist in almost infinite variety. Furthermore, vital mechanisms are not only characteristically different in each "species"; but they differ in each "individual" of the same species. In other words, what constitutes a "species" is a type or kind of mechanism which has a characteristic definiteness. Finally be it said, "organisms" (living things) are not only unique in their composition and structure, but they are also unique in the activities which have come to be recognized as vital functions. Taking them altogether, the activities of the varying forms of protoplasmic mechanisms constitute the functioning aspect of life.

**Scientific Value of the Mechanistic Approach.** When we think of life as a manifestation of energy in a protoplasmic mechanism, we are able to reason about vital phenomena in terms of cause and effect. The conception of *life* as reducible to a physico-chemical basis, has been remarkably fruitful. While we may never be able to unravel the intricate tangle of the scheme of life, and in our search for knowledge we may find some more fruit-

ful approach, of this conclusion we are certain—that by using a mechanistic hypothesis as a guide, the student of concrete phenomena can go much further than he could ever expect to go if inquiry were limited by dogmatic assumption.

### Characteristics of Living Matter

Although we are forced to admit that it is impossible at present to state final conclusions in distinguishing vital from other forces, we can bring the subject into perspective by describing approximately and in a somewhat imperfect way, what are the properties of living matter: its chemical composition, its physical constitution, its irritability, its motile properties, its powers of reproduction, its metabolic activity, and its organization into definite units, called cells. Not all of these characteristics of protoplasm need be discussed in detail in this place, for some of them are to be dealt with later. In this initial statement, let us confine our attention to the chemical and physical composition of the living substance—protoplasm.

**The Chemical Composition of Protoplasm.** It is through the study of protoplasm as a physical mechanism that we are able to know its distinguishing characteristics. It is impossible to distinguish between living and lifeless matter in terms of the ultimate materials of which they consist; for, as has been said, chemical analysis reveals that protoplasm contains no strange or peculiar elements. On the contrary, it is made up of the most abundant and most familiar constituents: carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, chlorine, sodium, potassium, calcium, magnesium, occasionally iron, manganese, iodine, copper, and possibly a few other equally common elements. No element characteristically vital can be present, for there is no difference in the weight of a protoplasmic body while there is life manifest in it and after life ceases; chemical analysis of dead protoplasm accounts for the entire weight in terms of the sum of the weights of the known elements present.

**Its Molecular Arrangements.** Since the distinction between living and lifeless matter is not to be found in the elements of which it is composed, the only alternative is to look for differences

in the ways in which the elements are combined. What is peculiar to living matter is that the molecules of which it is composed are enormously large and complex as compared with molecules of substances that have never been alive. Of the various classes of compounds that are especially characteristic, the most important are *proteins*, *carbohydrates*, and *fats*. These compounds are not found in nature except in living organisms or as products of protoplasmic activity. Carbohydrates and fats may be thought of as largely the pabulum of living matter, but the proteins are more than that. Protein is "the chemical nucleus or pivot around which revolve a multitude of reactions characteristic of biological phenomena."

**Proteins.** "Viewed from the chemical standpoint," says Underhill, "protein is seen as a huge molecule, complex in structure, labile in character, and therefore prone to chemical change. So large and intricate is the make-up of the molecule that chemists for generations have been baffled in their attempts to gain any adequate conception of its nature. At the present stage of our knowledge it is impossible to form any satisfactory definition of a protein based either on its chemical or physiological properties." All we know is that proteins consist of the elements carbon, hydrogen, oxygen, nitrogen, sulphur, and sometimes phosphorus or iron; that nitrogen is the distinguishing element; that the protein molecule may contain thousands of atoms; that proteins may be split up into many simpler compounds, some of these possessing a high degree of complexity; and that life never exists in the absence of proteins. It may be said also that the proteins of any species of organism are unique for that species; indeed, there is reason to believe that individuals differ as much in their proteins as they do in more obvious structural and functional characters. It has even been claimed that the proteins are the real basis of specificity.

**The Physical Structure of Protoplasm.** In general appearance, protoplasm is usually of a grayish pellucid color, somewhat granular or foam-like in some cases, homogeneous or almost glassy clear in others. In consistency it is a sticky, viscous semi-fluid, sometimes appearing almost solid. The ultimate physical make-up of protoplasm is *colloidal*. It is composed of an organized system of substances in solution, the particles of which are too small to

be seen under the ordinary microscope but are much larger than molecules. Many of the most characteristic properties of protoplasm depend upon its colloidal composition. What this composition is has been graphically described in many ways.<sup>1</sup>

**How Molecular Energy Is Made Vital.** The physical basis of life then is a physico-chemical complex. One of the most distinctive activities of protoplasm is that of trading in energy. It expropriates energy from surrounding nature—its environment. It does this by the exercise of an inherent capacity to surround or take into its body or mass other substances or masses of material and make the included substances or parts of it over into molecules which have a higher potentiality. When necessary to its continued functioning, the organism produces conditions that bring about a chemical change by which stored potential energy is released in kinetic form. The components of protoplasm, and especially the proteins, are extremely labile—that is, their molecules impounded in protoplasm or entering into its physical arrangements tend to change their chemical composition through processes of oxidation and deoxidation toward less or greater complexity. Thus protoplasm is ever changing, and these manifestations, this constant flux, are the best conception of what the biologist means by the life process. Protoplasm, the vital substance, is peculiarly prone “to change its composition under the stimulus of slight changes in the energy equilibrium between itself and its surroundings.”

**Vital Energy Not a Haphazard, but an “Ordered” Result.** While it is important to recognize that many of the properties of protoplasm inhere in the physical and chemical complexity of the peculiar materials of which it is composed, it is even more important to understand that no mere haphazard mixture of the components of protoplasm would be alive. The essential feature that endows protoplasm with life is the definiteness of the organization of the various heterogeneous ingredients into structural units. These units may be relatively simple or very complex. The simplest living structural unit of the protoplasmic mechanism is the *cell*. And it is significant that living matter whose structure can

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<sup>1</sup> See index, “Colloid” in Sharp’s *Cytology* as listed in Select Bibliography.

be observed and studied by use of instruments at hand is never found except as organized in these units.<sup>2</sup>

**The Cell—The Unit in the Life Mechanism.** Just as the electron is the unit of energy and the molecule the unit of substance, so the cell is the unit of the life mechanism. Some of the simplest and smallest animals and plants consist of but a single cell, while the bodies of the most highly organized and largest

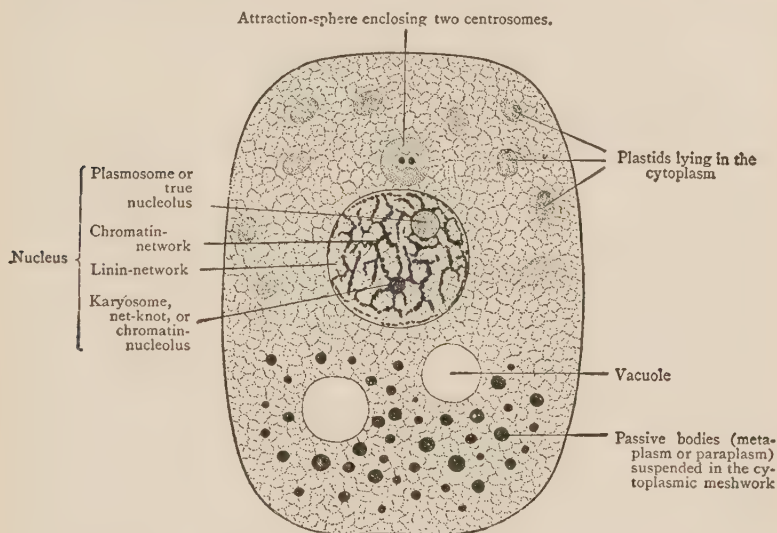


Figure 55. General Diagram of the Cell. (From Wilson.)

animals and plants consist of masses of millions of cells of many forms and related functions. Whatever the complexities of the organism as a cooperating vital mechanism, each constituent cell must be thought of as an individual. Each individual cell in a many-celled organism is a mechanism which carries on a complicated process of energy transformation within its own boundaries. This does not mean that in many-celled organisms the individual cell acts or can act independently. All the constituent cells of such an organism are interrelated both structurally and functionally; those of the same kind, united as tissue, affect each other; and those of different kinds are so interrelated organically that they

<sup>2</sup> In the so-called filterable viruses there may be life units of subcellular organization, but as yet nothing is known of their structure.

affect each other. Some groups of cells play the rôle of leaders in all sorts of activities; they initiate changes and control the actions of other groups of cells. In general, it may be said that all the cells of the organism are held together as a unit. Connective tissue forms the physical bond; functional unity is given to complex organisms by specialized tissue made up of nerve cells. These centralize or integrate the activities of the organism as a whole and endow the complex body thus actuated with individuality. The multicellular organism is not an anarchy, but a closely knit "cell state."

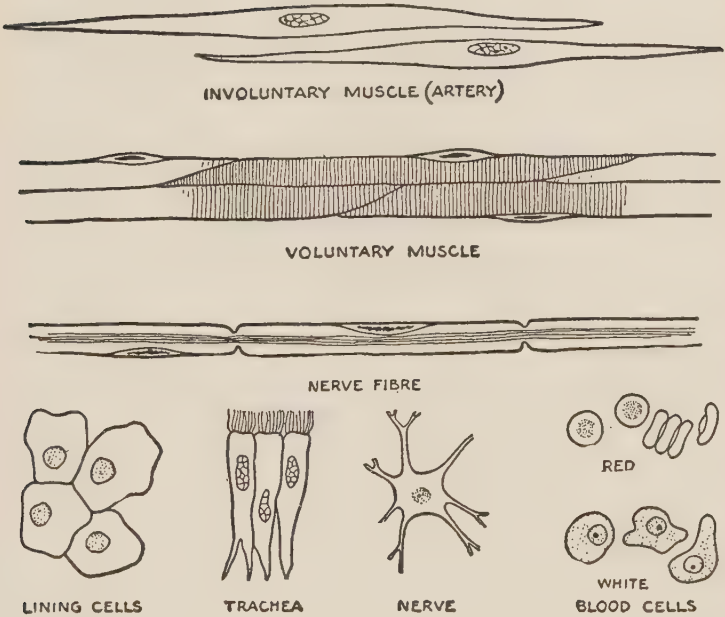
**The Functioning Parts of the Cell.** The typical cell is a more or less spherical mass of protoplasm containing a central body, the nucleus. According to Professor E. B. Wilson, the leading student of cells, the rest of the protoplasm outside the nucleus is the *cytosome*.

The *nucleus*, while it may have a great variety of forms, always contains a special kind of proteid material called *chromatin*.<sup>3</sup> This is believed to be the vehicle for the transmission of hereditary individual differences. In addition, we distinguish as other ingredients of the nucleus a fibrous network, *linin*, and a general nuclear ground substance.

The *cytosome* is usually a definitely organized system of structural components arranged with reference to certain lines of polarity and symmetry. Among the *formed bodies* in the cytosome we recognize a *central body* (centrosome), which is the focus of the energies employed in cell division; various cytoplasmic granules are suspended in the clear, more or less viscid ground substance—also a class of bodies called *chondriosomes*, whose form is often complex. All of these components of the cytosome have their definite places in the scheme of organization; each is essential to life, and all work together in the task of performing the functions of cell life, just as the various organs cooperate in performing the functions of the human body. Each cell is to be thought of as a complex physico-chemical mechanism, and the activities of each cell are determined by the peculiar characteristics of its mechanism. The mechanism of different cells differs in

<sup>3</sup> Named from the characteristic of the material which causes it to take readily a stain or color by which it may be distinguished under the microscope.

ANIMAL CELLS



PLANT CELLS

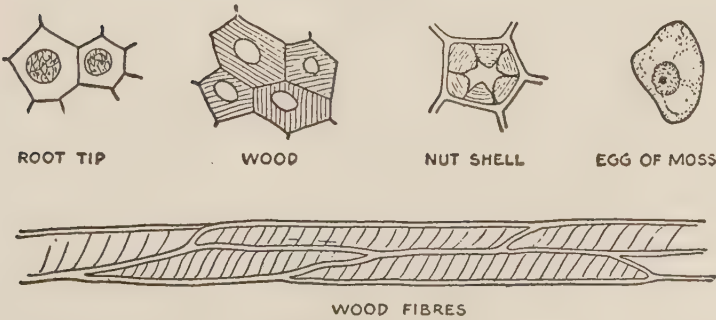


Figure 56. Animal and Plant Cells from Various Tissues. (From Moon.)

the details of its chemical composition, its physical state, and the organization of its components.

**Kinds of Cells.** While most cells are microscopic in their dimensions, some cells are relatively large. The "yolk" of a hen's egg, for example, is but a single food-gorged cell in which is stored a large amount of nutriment for the prospective embryo. Nerve cells, while of small bulk, may be extremely elongated, for a single microscopic cell may have a slender process (axon) that reaches from the tip of a limb to the spinal cord. Some cells are at the same time whole organisms, as in the protozoa (one-celled animals) and the protophyta (one-celled plants). These one-celled animals and plants may be very highly organized and specialized in spite of the fact that all of their operations must be carried on within the bounds of the mechanism of a single cell. Other cells are merely subordinate parts of an individual organism made up of millions of structurally related cells. Thus, within the body of man there are innumerable cells of diverse sorts, performing a great variety of special functions and differing accordingly in physical and chemical make-up. There are *epithelial* cells of various kinds (these for the most part forming the linings and surfaces of organs); there are *connective tissue* cells (specialized in many ways to perform the functions of packing tissues, cartilage, tendons, ligaments, bones, and fat); there are *muscular* cells (consisting of voluntary and involuntary muscle fibers); there are *nerve* cells, and there are *blood* cells, the so-called blood corpuscles.

**One-Celled Organisms.** The protozoa, one-celled organisms, constitute a very large group of animals. The protophyta, one-celled organisms, constitute a very large group of plants. Because of the difficulty experienced in determining the classification, and the advantage of distinguishing unicells from multicells, all one-cell organisms for certain purposes have been grouped as "protista." In contradistinction, the multicellular species remain broadly classified as animals and plants. And when these are classified, the animal phyla are given the characteristic ending of *zoa*; the plant phyla are given the characteristic ending, *phyta*.

Within the confines of a single enclosing cell membrane and with but one nucleus (sometimes several nuclei may be present)

the animal or plant carries on all of the characteristic vital functions. Within each cell the degree to which specialization of regions for different functions is carried out is amazing—for many of these unicellulars are extraordinarily complex, even more complex in some cases than are the simplest multicellular organ-

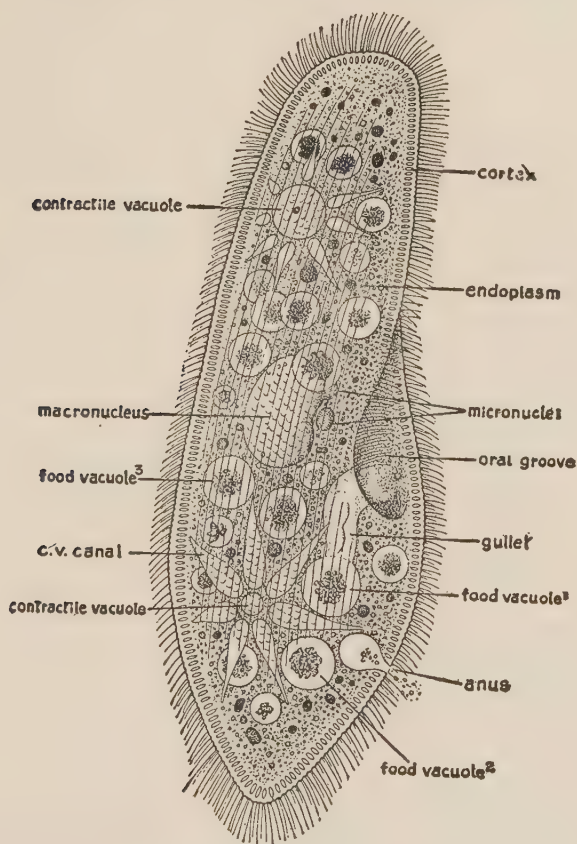


Figure 57. Paramecium. (From Newman.)

isms. This goes to show that complexity of the vital mechanism is not entirely dependent upon multicellularity but on the evolution of complementary functioning parts.

Some of these unicellular species tend to group themselves into colonies. These are not chance collections of individuals, but result from the fact that the products of cell divisions remain in

contact for relatively long periods and thus cell colonies instead of multicellular organisms are formed. Such cell aggregates are not usually true individuals, for each cell lives to itself and still remains a complete organism when separated from other members of the colony. Yet there may be a certain limited degree of division of labor among the members of such a cell colony. Thus,



Figure 58. *Amoeba Proteus* in Active Moving Condition: *c.v.*, contractile vacuule; *f.v.*, food vacuole; *n.*, nucleus; *w.v.*, water vacuoles; *p.* remains of pseudopodia. The arrows indicate the direction of protoplasmic flow. (Sedgwick and Wilson, from Moon.)

in certain species some cells remain solely nutritive and locomotive and others give up these functions and become reproductive. Complexity of organization is, however, not carried very far among unicellular aggregates as distinguished from multicellular bodies.

**Many-Celled Organisms.** In true multicellular organisms, both animals and plants (metazoa, metaphyta), real division of labor is accompanied by diversification in structure and in relation to the environment. A group of smaller units (cells) thus becomes organized into a larger, much more complex unit (a

complex individual), in which each cell remains an energy-transforming mechanism, and each kind of cell (organized as tissue) or related group of tissues (organ) carries on one or a few kinds of vital activities. This complex vital mechanism as a complete functioning organism, is the metazoan, and the more closely integrated it is the more specialized are its cells, tissues, and organs as parts. The least integrated types of multicellular organisms have fewest specialized types of tissues and organs. The basic structure in differentiation is the cell. The most closely integrated types of multicellular organism have the largest number of different kinds of cells and the most highly specialized cells.

**Tissue Cells and One-Celled Organisms.** While it is true in a sense that a single tissue cell, say a liver cell or a blood cell, is equivalent to a whole animal such as an amoeba or a paramecium, in another sense this is far from true. The amoeba or the paramecium is much more than a single cell; it is a whole organism. The liver cell is merely one center of physiological activity among millions of others that make up a whole man or a whole frog. Both the amoeba and the man are organisms, and in that they are equivalent. In a narrower sense, both the amoeba and a liver cell are cells, and are therefore, to that extent, equivalent.

Our dilemma is to some extent relieved if we admit that some organisms (protozoa) may reach a high degree of complexity and elaborateness of structure without multiplying life units or cells, but the best scheme for gaining increased complexity and specialization is one that involves first, a vast multiplication of cells, and second, a division of labor and consequent structural specialization of cells for a great variety of functions.

**Each Cell a Mechanism.** Every different type of cell is a machine for transforming molecules of high potential into molecules of low potential and releasing energy—by means of which it turns out some particular kind of work. A nerve cell is evidently constructed especially for receiving and transmitting stimuli. A muscle cell is built for contraction, a gland cell for secretion, an integumentary cell for protection. Every cell is living. The particular function it subserves is a vital function, and its life consists of the activities manifested by it. The particular

structural and functional relations of any given cell determine the life processes of that cell, and in a very real sense we may say that the life of a cell is the manifestation of the particular kinds of energy transformation peculiar to a special kind of mechanism.

**The Multicellular Organism as a Whole, a Mechanism.** An organism composed of many cells is not fully explained when it is viewed merely as the sum of the individual cells that make it up. It is more than this. It is an organic unit, not merely an assemblage of minor parts. Our task is to account for this unity of organization. The most satisfactory explanation of this is given by Professor C. M. Child: "The foundation of unity and order in the organic individual is the transmission of dynamic charge, 'stimulus,' 'excitation,' from one point to another in the protoplasm." In other words, unity is maintained by an elaborate system of intercommunications leading from a headquarters that issues the controlling impulses for the whole body. Unity or individuality is like a great business organization dependent for its efficiency upon a well-defined system of executives under one chief executive who correlates the activities of all departments and issues all orders for important operations. So long as the chief keeps in touch with the next grade of executives and they control the next lower officers, and so on down the line, the business is a true organism. This is quite analogous to the human cooperative arrangement in which such a system of officers is known as an organization.

Now a living organism that is really definitely organized has some one region of the body, technically known as the *apical region*, whence originate the main unifying impulses. Commonly, the apical region (apex) is the head, where lie the brain and the special sense organs. The parts behind the head are subordinate to the head and receive impulses from it. Parts further back are subordinate to all parts nearer the head and dominate all parts back of them. In other words, there is a gradient of dominance and subordination running from the head to the basal region. We know that the head end has a higher rate of metabolism (it lives at a more rapid rate) than any other part, and that there is a steady decrease in rate of metabolism for each increase of distance from the head. The head starts new impulses that continually

travel basalward, and each part of the axis from apical to basal regions takes orders from parts apical to it and gives orders to parts basal to it. All of these ideas have been abundantly demonstrated by experiment and stand on sure ground. Thus, unity in the organism, individuality, even personality if you wish, have a basis in an elaborate mechanism that works on known principles. There is nothing mystical or unknowable about these concepts. They go far to demonstrate the validity of the mechanistic point of view in the entire biological field.

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#### 2. How is this subject related to and differentiated from the group of natural sciences discussed in the preceding chapters—Astronomy, Geology, Physics, Chemistry?

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6. In what sense is biology a highly specialized branch of physics?

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J. Loeb, *The Mechanistic Conception of Life* [Univ. of Chicago Press, 1912], Influence of temperature, pp. 207-213; Effects of light, pp. 213-215; Effects of gravitation, pp. 215-218.

7. What are the characteristics of living things as distinguished from non-living things stated in terms of chemical composition, energy and mechanism?

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McFarland, *op. cit.*, Ch. III, The criteria of life, pp. 31-33.

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Bastian, *op. cit.*, Ch. II, The fundamental properties of living matter, pp. 21-42.

Loeb, *The Organism as a Whole*, Ch. II, Specific difference between living and dead matter and the question of the origin of life, pp. 14-39.

8. What are the subjects of interest of the following biological specialists:

(a) ecologist, (b) cytologist, (c) embryologist, (d) histologist, (e) ontologist, (f) morphologist, (g) anatomist, (h) physiologist, (i) dermatologist, (j) osteologist, (k) neurologist, (l) hygienist, (m) pathologist?

Weyssse, *op. cit.*, p. 7; Relation of zoölogy to allied sciences, pp. 512-514.

Sedgwick and Wilson, *op. cit.*, Biological sciences, pp. 7-9.

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9. How is "vital" energy distinguished from other forms of energy?

Osborn, *Origin and Evolution of Life*, pp. 48, 57 (lifeless energy); pp. 11, 18, 51, 55 (living energy); p. 14 (mechanical); pp. 12, 176 (of electricity); pp. 11, 12, 18 (of gravitation); pp. 12, 14, 53, 99, 100, 113, 254, 280 (of heat); pp. 12, 43-45, 48, 49, 71, 99, 100, 101, 113 (of light); pp. 10, 12, 14, 53, 280 (of motion); p. 26 (of radioactivity); pp. 13, 15, 19, 21, 285 (potential); pp. 13, 14, 21, 285 (kinetic); pp. 19, 278, 280 (latent); pp. 14, 16-18, 80, 87, 152, 280, 285 (storage).

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H. Bergson, *Creative Evolution* [N. Y.: Holt, 1911, Mitchell trans.], pp. 253-255.

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11. Historically, what were the views on the nature of life held by: (a) Thales—624 to 548 B. C.; (b) Anaximander—611 to 547 B. C.; (c) Empedocles—495 to 435 B. C.; (d) Aristotle—384 to 322 B. C.?  
H. F. Osborn, *From the Greeks to Darwin* [N. Y.: Macmillan, 1913], Ch. II, Among the Greeks, pp. 29-68.  
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12. What were some of the theories evolved after the days of Aristotle and before the modern scientific period?  
McFarland, *op. cit.*, Ch. II, Origin of life, pp. 20-30.  
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13. What were the two general schools of evolutionists in the eighteenth century?  
Osborn, *From the Greeks to Darwin*, Ch. IV, Evolutionists of the eighteenth century, pp. 106-151.
14. Distinguish between the views held by the two modern schools called "vitalists" and "mechanists."  
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Bastian, *op. cit.*, Ch. III, On some properties of crystals with observations on their mode of origin and on the mode of appearance of living units, pp. 43-61.  
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Weyssse, *op. cit.*, p. 4.  
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Lull, *op. cit.*, Chemical characteristics of protoplasm, p. 18.  
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19. What is a colloid; how does protoplasm differ from other colloidal substances?

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29. From the viewpoint of cell specialization what is the chief distinction between a unicellular body and a multicellular body?

McFarland, *op. cit.*, Ch. VII, The higher organisms, pp. 109-168.

30. What are the two characteristic parts of a cell—whether protozoan or metazoan—as they have come to be known through microscopic observation?

Newman, *Zoölogy*, pp. 57-60.

McFarland, *op. cit.*, Ch. V, The cell, pp. 93-101.

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31. What is the nucleus and what is its function thought to be?

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Wilson, *op. cit.*, pp. 84-97.

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34. Distinguish the *chromatin* from the *linin*.

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Sharp, *op. cit.*, pp. 25, 64.

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36. What are the functions of the nuclear membrane and the cell wall?

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37. What is the centrosome and what is its function?

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Wilson, *op. cit.*, pp. 435-437.
39. To what extent do colonial protozoans (one-celled individuals) become specialized functionally?  
Newman, *Zoölogy*, pp. 138-140.  
Shull, *op. cit.*, pp. 84-91.  
Weysse, *op. cit.*, Ch. III, Type protozoa, pp. 19-50.
40. To what extent do the cells of a multicellular body become functionally specialized in the development of organs?  
Shull, *op. cit.*, pp. 109-114.  
McFarland, *op. cit.*, Ch. VII, Higher organisms, pp. 109-168.  
Wilson, *op. cit.*, The cell in relation to the multicellular body, pp. 101-106.
41. In what sense is a cell in a highly specialized multicellular body still a complete vital mechanism, and to what extent is it dependent?  
Newman, *Zoölogy*, p. 54.  
Sharp, *op. cit.*, New conception of the cell, pp. 12-13; Ch. II, Preliminary description of the cell, pp. 23-31.
42. To what extent is a multicellular organism to be considered as an entity—each cell and part depending on the cooperation of every other cell and part?  
Loeb, *Organism as a Whole*, Ch. I, Introductory remarks, pp. 1-13.  
Newman, *Zoölogy*, Ch. VIII, The unity of the organism, pp. 77-85.
43. Distinguish between the elemental and the organismal theory of living matter.  
Newman, *Zoölogy*, pp. 77-81.
44. Defining life as a force, i.e., kinetic energy harnessed up to a protoplasmic mechanism, adapted to achieve certain objectives (adjustments), what is senescence, degeneration and death?  
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## CHAPTER XVII

### LIFE'S OBJECTIVES \*

**Use of the Word "Objectives."** The word "objectives" is not in good repute with the general biologist, the botanist or the zoölogist. It is not commonly found in the literature of that higher specialist who deals with the psychical aspect of organism—the neurologist. In these several fields of inquiry, attention is given to the mechanistic side of living things. The reason is that the idea conveyed has been the very center of an ardent controversy between those who hold firmly to the mechanistic approach and those who assume that all science should be undertaken with a view to establishing by evidence a conception of "purpose." Because of the bitterness aroused, and still arising, scientific students in the biological field have carefully avoided the use of such words as "purpose" and "objective." Of the two words, "objective" is more appropriate for the reason that it connotes "end." And every biologist is forced to recognize the fact that life depends on *adaptation*. When thinking in terms of mechanism, he uses the word "fit," and the phrase "survival of the fittest." We cannot avoid dealing with the notion that the mechanism in which and through which vital energy is developed and finds expression must "fit the circumstances" or be exterminated; and furthermore, we cannot avoid dealing with the fact that all organisms to a greater or less degree have a "tendency" or capacity to modify the circumstances so that the equipment with which each is endowed may work more efficiently—may continue to serve felt needs. Thus, each one of the mechanistic school of necessity develops some kind of a norm or standard for judgment as to what is "fit"; i.e., he develops a conception of biological "end"; he develops the idea, accepts the conclusion that organisms have a capacity to "select" between alternatives; he recognizes that each organism and all of them are confronted by "problems"—that life presents problems

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\* By Professor Horatio Hackett Newman (see note at the head of Chapter XVI).

for solution by non-human organisms as well as by mankind. It is in this sense and not in any other, that the term "objective" is here used.

**Recognition of Principle of Adaptation.** The subject is here introduced for consideration and discussion for the reason that this series of essays as planned in later chapters deals with "contributions of man" to the solution of life's problems. This chapter, therefore, introduces the subject of adaptation of species to environment to the end that we may first consider "the contributions of nature" to the solution of life's problems before the advent of human intelligence—i.e., before there was consciousness of dilemmas in which the human organism found itself. In a very real sense, non-humans have had and still have their dilemmas. Organisms are made aware of *need for adjustment and readjustment*. Organisms automatically react to stimuli—even where there is no nervous system—and their fitness is determined by the course taken. All living things are creatures which may be studied as having tendencies—in the same manner that the astronomer studies the sidereal universe. The biologist, however, must deal with "survival" and this is the modifying circumstance that warrants the use of the phrase "life's objectives."

### Ultimate Objectives

**Continuity and Abundance of Life.** Thus defining the phrase "life's objectives," we may proceed with a consideration of "ends"; then we may think of adaptation in terms of "means." First we may ask, what may be thought of as biological "ends" to be achieved, as "ultimate objectives"? Conception of adaptation in terms of "means" requires that the biologist recognize, (1) a tendency on the part of all organisms to so adapt themselves that "the stream of life" may be continued; and (2) a tendency to expropriate "goods" from environment and multiply. Biologists recognize that each "species" or protoplasmic mechanism must provide for itself mechanisms adapted to protecting itself, repairing itself, and ultimately replacing itself, otherwise the individual will become worn out by the life stream which runs through it like water through a mill and the species will disappear. If each

and every type or species does not provide for protection, repairs, and replacement, the biological end—"continuity" of the life stream—would not be assured; the development of vital energy would cease—for the mechanism of its production would pass out forever. Considering the perils to which all the several types of mechanisms or "species" are exposed, and their dependence on expropriation of the delicately adjusted complement of things needed to develop and maintain vital energy (to maintain what is called "the metabolic balance")—considering these facts, biologists agree that provision must be made for *abundance*. There must be increase in "goods"; there must be increase in numbers of mechanisms and species. These results considered as ends ("continuity" and "abundance") become a logical basis for the classification of means to end that are discussed in the two chapters that follow. As such, *continuity of life* and *abundance* are here premised as broad categories when thinking of "objectives"—whether the species is conscious of its biological needs or not. They are "ends" or "general tendencies" inherent in the very nature of protoplasm. The "life substance" is such that it has a tendency to make provision against its own extermination, to perpetuate its type and supply its needs. The tendency is inherent in the machine in which and through which the various other forms of energy are transformed into that state called "vital"; the tendency of protoplasm to "adapt" itself we may say is in the interest of continuity and abundance. Such is "the nature" of the mechanistic arrangement by means of which organisms operate on environment and use the substances expropriated for purposes of functioning, growth and development. For the present purpose it is not necessary to assume that such "ends" are either visualized or planned, even in man—for humankind in certain stages and conditions must be thought of as having made provision for meeting contingencies in the same manner as all other living things have done. Let us restate conclusions. Certain things organisms must do if they are to succeed: They must be able to draw upon the world's sources of energy in order to supplement losses of energy involved in the processes of living; they must be able to build up larger masses of living substance( to grow ); they must be able to discard archaic or obsolete parts or structures that no longer serve a useful purpose; they must be able to continue successful life com-

plexes beyond the lifetime of individuals (to reproduce); and for fullest success life must become as varied and as abundant as the environment invites or permits.

**The Summum Bonum of Organism.** The best thing that an organism can do in relation to life is to reproduce successful adaptive complexes as rapidly as possible up to the limit of the opportunity available. This implies continuity of the life stream through reproduction of its own kind. It is its most important response to "the vital urge." Beyond a certain point, numerical increase of the species is a detriment; for it means that the necessities of life have to be shared by too many, and none can realize their fullest development. But nature has an automatic regulator for overproduction in that a struggle for existence keeps down reproduction to the point where only the relatively fit individuals survive and the relatively unfit perish. Overproduction has its values in forcing higher standards of survival upon a species.

### Immediate Objectives

If the "ultimate objectives" or ends of organisms may be said to be *continuity* of life and *abundance*, the "immediate objectives" may be thought of as the development of the means of (a) self-protection of the organism—the mechanism in which life inheres and through which it expresses itself; (b) self-maintenance or upkeep of the mechanism—involving the acquisition of food, its storage, its transformation into more usable forms, its distribution to parts in need of it, its utilization in the generation of power and heat, in growth, in repair, in elimination of wastes; (c) self-replacement or the production of more mechanisms of the type found to be fit—the reproduction of the same species; (d) and adjustment to environment with a view to maintaining proper relations with that which is external to the vital mechanism—adaptation, by means of which the major objectives may be more readily and more abundantly attained. Let us get before us clearly what is meant by these four immediate objectives before considering each in detail.

**1. Self-Protection.** Self-protection and self-maintenance must not be confused. The former means the saving from destruction

of the mechanism as a whole, while the latter means keeping up the mechanism at a rate of efficiency which will enable it to function successfully—"keeping fit." The distinction may be made clear if we think of a non-living mechanism such as an automobile. The adaptations of the automobile for self-protection are bumpers, fenders, paint, locks, gauges and indicators of functional dangers, lights, adequate strength and ruggedness of parts to stand the racket of motoring. The adaptations for self-maintenance are not fully duplicated by an automobile, for it cannot repair itself. But there are numerous devices for reducing wear and loss of efficiency, such as lubrication, purification of air and gas, and the renewal of electric power; and there are equivalents of digestive functions in the carbureter, which render the crude fuel more available for energy transformation; while the motor is the equivalent of the muscle that has acquired and stored energy-forming materials ready to release it in the form of mechanical work when the spark of a nerve impulse ignites it. It is not our purpose in the present discussion to describe in detail nature's vast variety of protective devices. These are much more elaborate and varied than those devised by man to protect his machines. This chapter deals with principles rather than with examples. The succeeding chapter goes into detail about the various devices for self-protection and self-maintenance.

**2. Self-Maintenance.** The multicellular organism is unlike a non-living machine such as a motor car in at least two essentials: (a) in the organism the motor parts are muscle cells, each of which is a motor—the power plant being a combination of millions of small motors harnessed together; (b) in the organism the structural tissues (made up of cells and these in turn of molecules), mechanisms and molecules are constantly changing their composition. The steel of the motor car in contradistinction remains the same throughout the life of the car—except, of course, for wear and possibly crystallization. Both the individual cells and the molecules of the living substance that make up essential parts of the vital mechanism are constantly breaking down; they first wear out or are destroyed, and the molecules are chemically changed with release of energy into more stable, simpler and less highly energized compounds. Thus "organisms" as living ma-

chines use up their own units of structure piecemeal in their operations—and unit by unit, molecule by molecule, they are replaced. It is somewhat like a ship at sea which has many motors and carries a complement of “extras”; it carries along its own repair shop; when one motor wears out, another is put in place without stopping the ship. If the pistons or gears of the motors wear out, these parts may be replaced. Now, if we may assume that some process were invented by which the mechanical parts would use up some of their molecules of steel for developing energy, and there was some way of replacing these molecules, our analogy would be more true to life. Because old cells are worn out in the living machine and the molecules are broken down in the development of power, it is necessary to provide for renewal both of cells and substance constantly by drawing structural materials and energy-containing substances from the environment; and after they have been expropriated from nature they must be refined in special ways and made up into all sorts of special living “stuffs” characteristic of the various parts of the mechanism. This is one of the outstanding differences between living and lifeless substances—that living substance is capable of self-maintenance. Thus the living machine when operating normally does not wear out, but up to a point actually becomes stronger and more efficient. It may, however, deteriorate if not sufficiently used—or if used too much without being given a chance to rest and restore itself. The living machine does finally become obsolete but this is provided for by reproduction and not by maintenance. This question is discussed on page 291.

**Metabolism.** We designate the whole process of cell structural change and the traffic of energy exchange between the organism and its environment as *metabolism*. The building-up phase—the phase during which there is structural upbuilding and cumulation of energy-containing substances from the environment, the process by which these substances are worked over and elaborated into living substance—is known as *anabolism*. The breaking-down phase—during which cells are wasted and the most complex molecules, such as those of the proteins, the carbohydrates or the fats are combusted and thus broken up into simpler compounds less

rich in energy—is known as *katabolism*. In young organisms the anabolic phase—especially in its cell-increasing aspect—exceeds the katabolic, and the increase in mass ensues; this we call growth. In mature organisms a sort of equilibrium is established between the two phases of metabolism and the organism remains at a relative standstill so far as mass and structure are concerned. In senescent organisms the katabolic phase gains slowly upon the anabolic and there ensues a gradual wasting away of mass and a lowering of rate of chemical activity which culminates and finally terminates in death. Death is merely a state of slowing down of certain metabolic processes beyond the point at which wastes can be eliminated and the necessary steps in energy traffic can go on.

**The Capture and Storage of Energy by Plants.** The first step in the metabolic cycle is that of securing new energy from the environment. The chief source of available new energy in our planet is the sun's heat and light. Heat may be absorbed directly by all organisms but cannot be made into substance because it is not substance itself but merely a disturbance of the molecules—an increase in their vibrations. Heat hastens chemical changes but does not furnish new materials. Light likewise appears to be a disturbance in materials rather than material substance itself; but by means of light, plants are able to take the first step in the capture of new energy from the environment.

**Photosynthesis.** In all green plants there are in the cells exposed to light numerous green bodies known as chloroplasts. The green substance is called chlorophyl and it is known to be the medium through which plants capture energy. The raw materials used are carbon dioxide and water, and the energy necessary for the chemical operation is sunlight. Green plants cannot produce new food in the dark. The water and carbon dioxide are combined first to form a compound called formaldehyde, but this quickly goes over into glucose ( $C_6H_{12}O_6$ ) in which six carbon atoms are combined with six water molecules. Glucose readily changes into sugars and some of the sugars may be changed into starch, in which form plants commonly store energy for future emergencies. Plant sugars and starches furnish vast supplies of food for animal consumption.

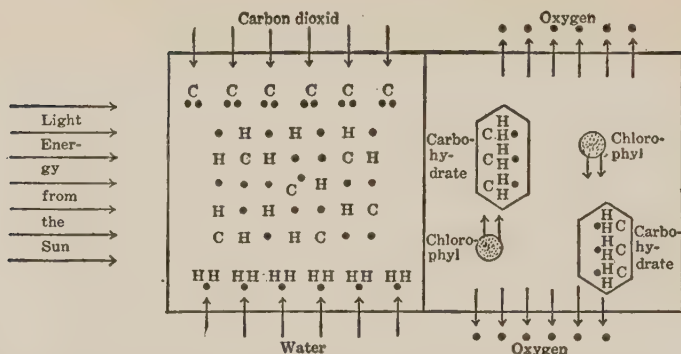


Figure 59. Photosynthesis. Starch making takes place in two stages; in the first the raw materials, water and carbon dioxide, are broken up into their constituent parts—carbon, hydrogen, and oxygen; in the second these elements are recombined into carbohydrates, and the surplus oxygen is set free. The energy for this process is sunlight; the transformations are brought about by chlorophyl. (From Gruenberg.)

**Protein and Fat Synthesis.** Plants are able to combine the soluble sugars with nitrogen-containing substances in the soil in order to form proteins and these proteins are also used by herbivorous animals. Fats are synthesized by plants in the form of vegetable oils and are due to a rearrangement of the carbon, hydrogen and oxygen molecules in carbohydrates. They are said to make glycerine and *fatty* acids out of glucose. Three molecules of fatty acids combine with one molecule of glycerine (glycerol) to form one molecule of fat. Fats and oils are mainly storage products and serve as important reserves for both animals and plants. Thus we see that animals and plants (plants especially) are to be viewed as chemical laboratories engaged in the manufacture (synthesis) of food (energy-containing compounds) and in storing it and transforming it into more readily available compounds used for growth and repair of organisms—for mechanical work, and for reproduction of “species” of mechanisms which, in the trial and error experience of living things, are found to be adapted to carrying on the vital processes in the environment to which each particular type or species is adapted.

**Animal Foods.** All animals depend on foods originally expropriated from nature by plants. No animal is able to manufac-

ture foods out of really elementary materials such as  $\text{CO}_2$  and  $\text{H}_2\text{O}$ , but all depend directly or indirectly upon energy already captured by plants. Thus, herbivorous animals use plant foods directly, carnivorous animals take at second hand the plant foods that have been worked over in the bodies of herbivorous animals, while omnivorous animals use both plant and animal foods. If we include water, oxygen, and salts as auxiliary food elements (and why should we not?), we must create a special category for them. These auxiliary elements are essential because they are con-

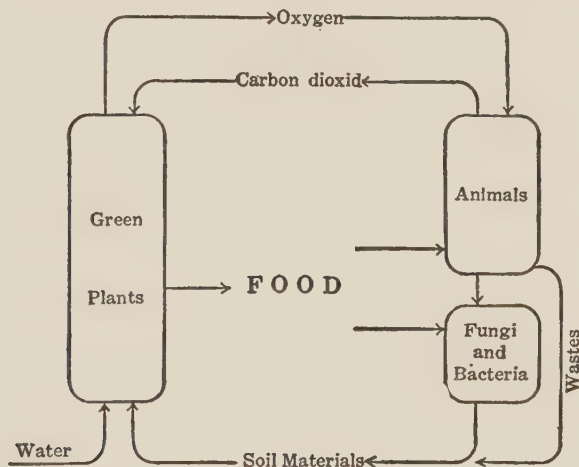


Figure 60. The Interrelation of Organisms. (From Gruenberg.)

stituents of protoplasm. When thinking about vital mechanisms, therefore, we must deal with various specialized parts of the organic machine adapted to taking them in and incorporating them into living stuff. It is a condition precedent to life that water, oxygen, and needed salts shall be present in the environment of the organism; and also that each organism be equipped with the means of taking these elements in when and as needed. It is known that a large supply of water is essential to active metabolism and that too much water or too little lowers the efficiency of the machine. If too much water is removed, as in profound desiccation, the organism may go into a dormant state, but may be restored to activity by renewing the water supply. Similarly, the increase or decrease of the oxygen supply will, like a change

in the draught of a furnace, accelerate or retard the metabolic rate, and this according to known laws.

Another important aspect of the organic mechanism is that it works properly only when the composition of its materials is kept at or near the point of chemical neutrality. If it becomes slightly acid or slightly alkaline the cogs clash and the machine gets out of gear. There are, fortunately, numerous devices in the organism

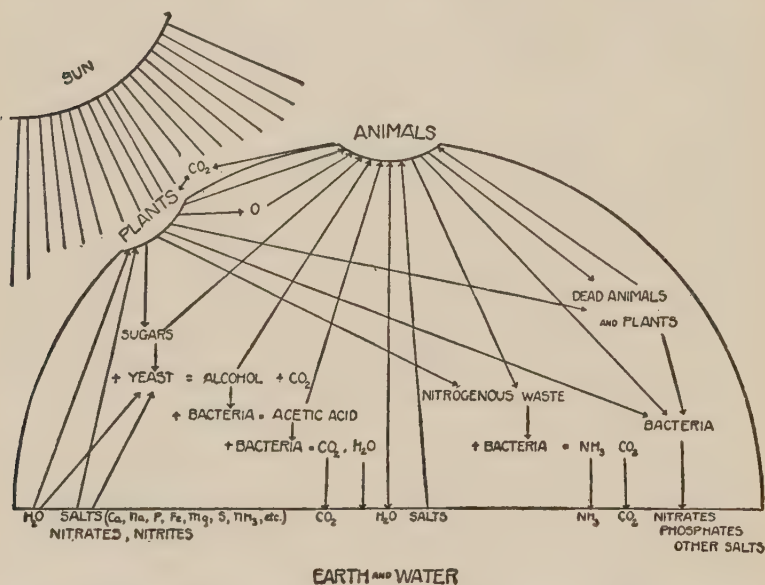


Figure 61. Earth and Water Cycle. Diagram illustrating the cycle of living matter and energy in animals, plants, yeast, and bacteria. (After Calkins, from Moon.)

whose function it is to restore chemical equilibrium or to maintain the acid-base balance at the point of greatest efficiency. Some of these will be discussed in the next chapter.

There are waste products in all metabolic processes and these must be eliminated as rapidly as formed in order that the chemical equilibrium of the working parts may be maintained and the machine may work with unimpaired efficiency. Thus, in animals carbon dioxide is a universal by-product of the combustion of carbon compounds. Urea is a common by-product of the splitting up of proteins and there are numerous other waste substances

whose presence in any but minute amounts would seriously damage the machine. These are eliminated through various systems of organs to be described later.

**3. Reproduction.** One thing the organic machine can do that no man-made machine can duplicate; by processes of division it

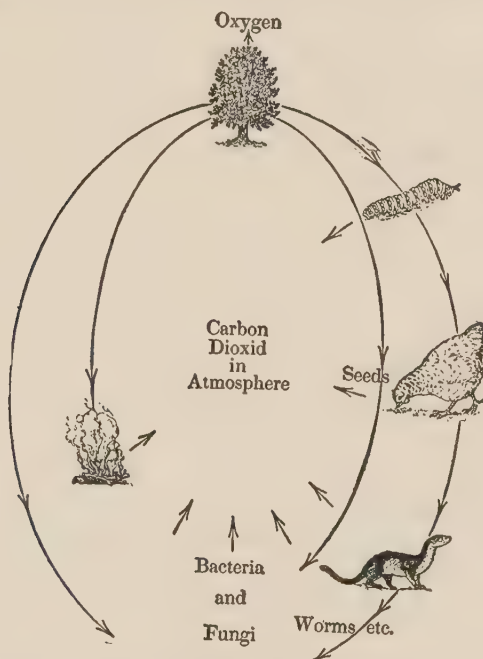


Figure 62. The Carbon Cycle. Fires and all kinds of animals are constantly giving out carbon dioxide. Green plants (represented by the tree) withdraw this carbon dioxide from the atmosphere and return oxygen. The material of the green plant is made up, in part, of the carbon derived from the carbon dioxide. This material serves as fuel for fires and food for animals. Animals oxidize this material; or *they* are eaten by other animals. Finally, the carbon of larger plants and animals is oxidized by bacteria and fungi, and returned to the atmosphere. (From Gruenberg.)

can give rise to new individuals of its own kind. The individual life mechanism is limited in its period "to run." It finally loses its capacity to carry on. Some of the great trees are said to have lived for thousands of years; giant land tortoises have been known to live for upwards of two hundred years; the age of man may slightly exceed a century but is much less on the average; the age

of a horse or a dog is usually less than twenty years; the age of a rabbit or a rat is only two to five years; many insects have but one year or less of individual life. In order that the species may not become extinct, new individuals of the same type must be produced by the old. The process by which this is done is called reproduction.

Essentially, reproduction is a phenomenon of isolation of an outlying part of the parent in such a way that the individuality of the parent ceases to dominate the straying part. Such a part is then able to assert its independence and to begin the process of growth and differentiation which we call development. It is the view of many biologists today that reproduction is essentially a process of senescence. When the organism is physiologically young, in the sense that the rates of the metabolic processes are high and the impulses from the dominant region (apical region) are able to travel with sufficient speed or intensity to reach every part of the body, there is no chance for physiological isolation of any part; and therefore, the individual holds together as a single organism. But if the metabolism of the dominant region slows down, as it does when the organism ages, the dominance of the apical region or regions can no longer reach all parts, and the parts not reached are likely to become physiologically independent and later to break loose physically as new individuals. This holds whether the emancipated parts are single cells (germ-cells) or masses of cells (buds, zooids, twins, etc.). So long as an adequate sample of living substance from the body of an individual is released from the control of the parent organism, it has the capacity to become a whole new individual. Thus the process of reproduction is a sort of regulatory process or one involving the restitution of a whole organism from a part of an organism. The different devices used in reproduction are to be discussed in the next chapter.

**4. Adaptation.** Adaptation may be defined as that property of living organisms by virtue of which the organism, through its mechanism, so modifies or adjusts itself that it improves its capacity to accomplish the other three "immediate objectives" of life above named—self-protection, self-maintenance, and reproduction. In general we may think of two kinds of adaptations: the adapta-

tions (a) of an organism as a whole to its environment; and (b) of the special organs for the carrying on of functions within the organism itself. It is difficult to draw the line sharply between these two categories, for some structures that seem to be significant chiefly in view of certain features of the environment may also be necessary for internal functioning. For example, the mandible may be used to change environment, as when a beetle bores a hole or a beaver gnaws down a tree to build a dam. And the same mechanism is used to apprehend and masticate food.

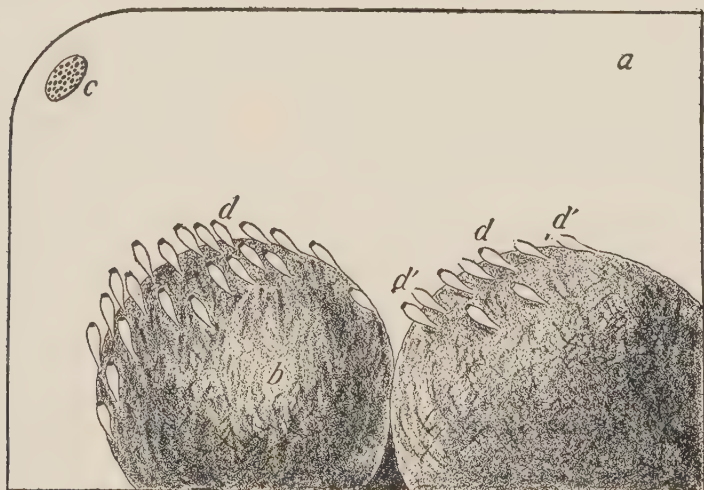


Figure 63. Growth of Fungus. Growth of the fungus *pilobolus* on horse manure, *b*, placed under a belljar, *a*, the exterior of which was lined with black paper except for the orifice at *c*. From resultant action of apogeotropic and specially heliotropic stimuli, the black sporangia are discharged accurately against the orifice. (From Macfarlane.)

**Natural Selection.** The history of life has been characterized by constant changes in organisms more or less directly correlated with rhythmic changes in the environment. During periods of relatively rapid change in the geologic and climatic features of the world, changes in organisms have been rapid, and during relatively stagnant periods, geologically speaking, evolutionary changes in organisms have been slow. All we know for certain is that such a correlation between organism and environment exists. We do not understand the exact causal relation between organic and

inorganic changes. The one theory by which we are best able to account for the adaptiveness of organisms is Darwin's theory of "natural selection." According to this view, the reason why most organisms show such a high degree of fitness or are so well adapted to the environment is that only the sufficiently fit individuals are able to survive and to reproduce their kind. If the struggle for existence becomes keen, the criteria of survival become more rigid and a higher degree of fitness is demanded in order that the individual may succeed in living and reproducing. Under hard conditions we would then expect fairly rapid improvement in adaptiveness, while under protected or easy conditions many relatively poorly adapted individuals would survive and perpetuate their kind. Selection does not account for the origin of new adaptive characteristics, but acts only as an arbiter among those that appear. Later on, we shall attempt to show that mutations and combinations furnish the raw material for selection from which to choose.

**Relation of Adaptation to the Cosmic Order.** In a stimulating book entitled "The Fitness of the Environment," Professor L. J. Henderson points out that the environment fits the organism as exactly as the organism fits the environment. The environmental complex of life today is absolutely unique. Hardly an element in it could be dispensed with or changed for something else without causing the extinction of life or at least changing its character so profoundly that it would hardly meet our present definitions of life. One must consider both the organism and the environment as inevitable end-products of cosmic processes of a larger order. Fitness of each to the other (the vital mechanism and environment) is to be expected. If unfitness were present that would constitute the real problem.

**Unfitness in the World.** Older ideas about the universal fitness of all organic things are gradually giving way before a growing conviction among modern biologists that fitness is at best relative and that there is a vast amount of unfitness in organisms. There is a reason for much of this. Organisms are conservative. Because of the mechanism of heredity each species tends to hold to and transmit characters of ancestors that have long lost their adaptive significance or their usefulness. Thus man has quite a

good tail but it is of no use to him, and the structure has become so diminutive that it is completely imbedded in surrounding tissue. He has a full set of muscles, for moving his ears, that have no adaptive value. His vermiform appendix, his third eyelid, the lanugo or embryonic down that covers the six-months fetus, and

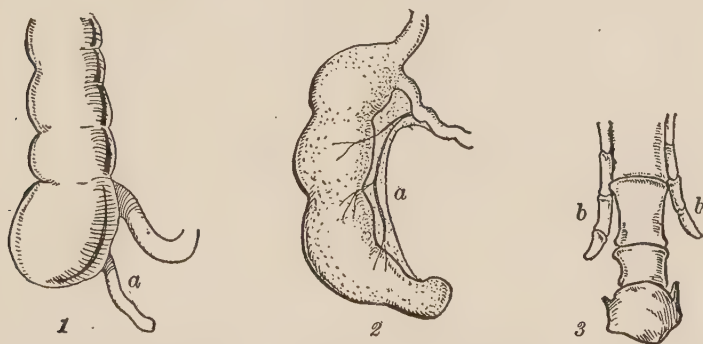


Figure 64. Vestigial Structures. The vermiform appendix, *a*, in some mammals is reduced to an insignificant trifle, as in man, 1; in other mammals, as in some of the rat family, 2, it is capable of holding a considerable amount of food in the process of digestion. The horse walks on his third toe, 3, the others being entirely absent, or represented in part by the reduced "splints," *b*. (From Gruenberg.)

a long list of other characters, are useless and are carried along merely because they are inherited. Man has simply never lost these characters. There are, then, adaptive characters and there are non-adaptive characters. The tendency to look upon all life as perfect and every structure or function as adaptive is a relic of the special creation conception and the idea of design in nature. Let us view things as they are and not read into them too much of what we believe they should be.

### QUESTIONNAIRE WITH READING REFERENCES

- I. What meaning must be given to the phrase "life's objectives" to make its use consistent with scientific biological reasoning?

D. S. Jordan and V. L. Kellogg, *Evolution and Animal Life* [N. Y.: Appleton, 1908], Ch. XVI, Adaptations, pp. 327-346.

R. S. Lull, *Organic Evolution* [N. Y.: Macmillan, 1926], Causes of extinction, pp. 225-228.

H. F. Osborn, *The Origin and Evolution of Life* [N. Y.: Scribner's, 1917], pp. 143, 155-159, 188-192, 194, 211, 214, 237-238.

J. M. Macfarlane, *The Causes and Course of Organic Evolution* [N. Y.: Macmillan, 1918], Ch. IX, Law of proenvironment, pp. 205-242; Ch. XXII, Operation of the law of proenvironment in the evolution of man, pp. 629-651.

J. Loeb, *The Organism as a Whole* [N. Y.: Putnam's, 1916], Ch. XII, Adaptation

to environment, pp. 318-345; Ch. XIV, Death and dissolution of the organism, pp. 349-370.

L. J. Henderson, *The Fitness of Environment* [N. Y.: Macmillan, 1924], Ch. I, Fitness, pp. 1-37; Ch. II, Environment, pp. 38-71.

2. Thinking of the problem of survival with which organic species is confronted (the fact that all organisms as protoplasmic mechanisms must adapt their structures and functionings to environmental conditions, or adapt environment to the mechanism in which vital energy manifests itself), what are assumed to be the most general biological "ends" or "tendencies" or "objectives" which biologists assume as criteria for determining whether a species or type is "fit"?

Osborn, *op. cit.*, pp. 251, 276-277.

H. Bergson, *Creative Evolution* [N. Y.: Holt, 1911, Mitchell trans.], pp. 26-27.

C. J. Herrick, *Introduction to Neurology* [Philadelphia: Saunders, 1916], pp. 18-19.

3. How is the idea "continuity" distinguished from "abundance," and why are these criteria of "fitness" of an organism to be regarded as "ultimate"?
4. How are the "ultimate" criteria of fitness, i.e., adaptation to assure the "continuity" of the life stream, and "abundance" of species and of the materials utilizable for the transformation of energy—how are these "ultimates" distinguished from "immediate" adaptations?

5. Taking the view that "ultimates" relate to final results or ends and "immediate" objectives relate to mechanism as means to end, what are the most general classes of "immediate" mechanistic adaptations to be taken into account in determining fitness to continue the life stream?

Osborn, *op. cit.*, The four complexes of energy, pp. 18-23.

Macfarlane, *op. cit.*, Ch. VIII, Pentamorphogeny or the five cooperating causes in organic evolution, pp. 174-204.

6. What is meant by "protection" in terms of structure?
7. What is meant by "maintenance" of mechanism as distinguished from "protection" as the terms are used in the text?
8. How is the phrase "self-preservation" of structure to be distinguished from the objective "continuity" of the life stream?
9. What is meant by "reproduction" as related to "continuity"? Distinguish the structural means from the end.
10. What is the subject matter of "ecology" as distinguished from the vitalistic theories of "evolution"?
11. What is the significance of the common attributes of cell structure and function when considering "fitness" for continuity?

H. H. Newman, *Outlines of General Zoölogy* [N. Y.: Macmillan, 1925], Ecology, p. 10; Ch. XXXI, Ecological aspects of zoölogy, pp. 367-369.

E. Strasburger, *et al.*, *Text-book of Botany* [London: Macmillan, 1903, Porter trans., 2nd ed. rev. by Lang], Structure of the cell, pp. 51-78; Circulation of liquids and gases, pp. 175-200; Movements of protoplasm, pp. 240-245.

## 12. What is meant by "metabolism"?

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J. M. Coulter, C. R. Barnes, and H. C. Cowles, *Text-book of Botany* [N. Y.: American Book Co., 1910, 2 vols.], Vol. I, Pt. II, Ch. I, Material income of plants, pp. 297-322; Ch. II, Material outgo of plants, pp. 323-355.

C. E. Marshall, ed., *Microbiology* [Philadelphia: Blakiston, 1921, 3d ed.], Pt. II, div. II, Ch. II, Mechanism of metabolism, pp. 203-220.

## 13. What is the "biological purpose" of chlorophyl in green plants?

Osborn, *op. cit.*, pp. 40-42, 48, 51-53, 99-101.

J. McFarland, *Biology, General and Medical* [Philadelphia: Saunders, 1918, 3d ed.], p. 57.

W. F. Ganong, *The Living Plant* [N. Y.: Holt, 1922], Ch. II, Prevalence of green color in plants, and the reason why it exists, pp. 16-46.

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B. M. Duggar, *Plant Physiology* [N. Y.: Macmillan, 1922], Ch. IX, Intake of carbon and the making of organic food, pp. 195-225; Ch. XVII, Light relation, pp. 415-435.

J. Y. Bergen and O. W. Caldwell, *Practical Botany* [Boston: Ginn, 1911], see index "Photosynthesis."

## 14. What is meant by "photosynthesis"?

Strasburger, *et al.*, *op. cit.*, pp. 194-206.

Coulter, Barnes, and Cowles, *op. cit.*, pp. 363-372.

G. Haberlandt, *Physiological Plant Anatomy* [London: Macmillan, 1914, Drummond trans. from 4th ed.], Ch. VI, Photosynthetic system, pp. 261-301.

J. M. Coulter, *Text-book of Botany* [N. Y.: Appleton, 1908], Photosynthesis, pp. 18-21.

## 15. What is the biological significance of the production and use of proteins by organisms?

A. P. Mathews, *Physiological Chemistry* [N. Y.: Wm. Wood, 1925, 4th ed.], pp. 118-121.

Coulter, Barnes, and Cowles, *op. cit.*, Synthesis of proteins, pp. 377-380.

## 16. What is the biological significance of the production of carbohydrates and fats by organisms? Discuss in terms of aids to combustion and the release of kinetic energy.

W. H. Howell, *A Textbook of Physiology* [Philadelphia: Saunders, 1924, 9th ed.], Ch. XLVIII, Nutritive history of carbohydrates and fats, pp. 922-936.

## 17. How may living things be classified from the viewpoint of the means employed for obtaining or producing potential and kinetic energy? Discuss in terms of those which collect and store potential energy, and those which transform the stored potential and kinetic form.

Newman, *Zoölogy*, p. 44.

Strasburger, *et al.*, *op. cit.*, pp. 1-5.

## 18. What is meant by "protons" ("protists" or "protista") and how do these relate to "continuity" and "abundance"?

## 19. What is meant by "phytons" ("phytists" or "phyta") and how do these relate to "continuity" and "abundance"?

## 20. What is meant by "zoöns" ("zoöists" or "zoa") and how do these relate to "continuity" and "abundance"?

## 21. What is meant by "foods"?

Mathews, *op. cit.*, Ch. VII, Raw materials or foods, pp. 310-329.

## 22. How are the substances and energies extracted by organisms from environment applied to overcome obsolescence of type?

Newman, *Zoölogy*, Adaptation, p. 46.

Lull, *op. cit.*, Ch. XIV, Recapitulation, racial old age, extinctions, pp. 213-228; Ch. XX, Aquatic adaptation, pp. 316-336; Ch. XXII, Volant adaptation, pp.

- 347-367; Ch. XXIII, Cave and deep-sea life, pp. 368-392; Ch. XXIV, Desert adaptation, pp. 393-408; Ch. XXVIII, Origin of vertebrates, pp. 460-476.
23. How are the substances and energies extracted by organisms from environment applied to overcome senescence or mechanistic degeneration?
- Newman, *Zoölogy*, Ch. XXVII, Modes of reproduction, pp. 305-319.  
 Strasburger, *et al.*, *op. cit.*, pp. 273-276 (reproduction-rejuvenation).
24. How are the substances and energies extracted by organisms from environment applied to maintenance?
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 Strasburger, *et al.*, *op. cit.*, Nutrition, pp. 160-170; Growth, pp. 223-224.  
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25. What is the significance of parasitism and degeneracy?
- Lull, *op. cit.*, Ch. XVII, Parasitism and degeneracy, pp. 263-278.
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27. Give a brief account of the development of the theory of cosmic evolution in its relation to life.
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## CHAPTER XVIII

### NATURE'S DEVICES FOR ASSURING CONTINUITY \*

**The Stream of Life.** It is now accepted as a scientifically established truth that all living things today are the progeny of previous living things and that there has been continuous lineage of ancestors back to the dawn of life. No one has ever demonstrated the origin of a new organism from non-living materials. Yet, until first Redi, and later Pasteur, overthrew the idea of spontaneous generation (abiogenesis) the prevailing belief among biologists was that life might arise spontaneously. Life, then, may be viewed as a streaming process augmented by generations of individuals—tending to increase its volume to the maximum and to radiate into as many new channels as it is possible to develop the protoplasmic medium. Various types of structural or functional specializations in the bodies of organisms enable the stream of life to invade new territory and exploit new fields.

**Progressive Evolution—Adaptation to Facilitate and Perpetuate the Streaming Process.** From a materialistic or structural viewpoint, progressive evolution may be interpreted as an adaptation of organism in such manner as to facilitate and perpetuate the stream of life—a gradual changing, an altered elaboration of transmissible characters in types of protoplasmic arrangements calculated to perpetuate the stream of life, to multiply its currents, and to enable each organism to find a way into new fields where conditions may be favorable to survival. Because the mechanisms (in which and through which vital energy finds expression) are plastic and labile, there is an ever-present need of protecting its mechanisms from violence. The vital mechanism is adapted to transform potential into kinetic energy. Life may be thought of as a result of “upsets” in the atomic, molecular, or grosser physical systems—to disturb the balance in parts or par-

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\* By Professor Horatio Hackett Newman (see note at the head of Chapter XVI).

ticles of animate or inanimate nature expropriated by an organism for its use. The mechanism adapted to this end (the machine in which vital energy is released by upsetting the environmental balance) is a fragile, plastic, vulnerable, and unstable thing. The "streaming process" depends on creating this disturbance and at the same time on maintaining its own system and balance. Thus, as different forms of released energy are made dynamic in vital mechanism, the resulting "forces" operating on external mechanisms offer a continuing menace. In other words, the very life process creates needs that must be attended to if continuity of life is to be assured. And the satisfaction of these needs gives rise to specific adaptations.

**General Classification of Protective Devices.** As pointed out in the preceding chapter, the several devices evolved by organisms for assuring continuity of the life stream may be divided into four general classes: (1) devices for *protection*; (2) devices for *maintenance* of vital functions and upkeep of plant; (3) mechanisms of *growth* and *development*—adaptation, enlargement, and extension of "plant"; (4) mechanisms of *reproduction*—devices for replacement to provide against obsolescence of structure and for changes in type. These terms used to describe the general aspects of organic structure and functions are made familiar to us in our dealings with non-living mechanisms. The words and phrases used, therefore, need no further explanation or definition. They are terms in common use. They are applied to the physical "plants" and mechanisms by means of which man has been able to deal more effectively with his environment. They are terms used to describe the machines by which we exercise control over environment when acting individually and collectively. And it is significant that the same terms may be used when describing and discussing human inventions and devices as when describing bodily structure and functions.

### **Protective Mechanisms Evolved by Nature—Defensive Devices**

When we view life and vital mechanisms as engaged in continuous warfare against inimical environment, we are not sur-

prised to find that practically the same devices are used by animals and plants as are used by man in carrying on war activities. As a matter of fact, we find in use by one or another, offensive and defensive armor, protective coloration and camouflage, false insignia or flags, poisonous and nauseous gases, espionage or means for learning of the approach of danger at a distance, varying signals to members of friendly groups, cooperation of large numbers for the common safety, identification marks by means of which each may distinguish his own kind, the cooperation of two or more "allies" for mutual offense and defense, the capture and enslavement of one species or kind by another in order to further the welfare of the captors. These and many other schemes are repeatedly found actually in use by non-human species, many of which are very low in the organic scale, and which possess little or no intelligence. The arts of warfare elaborated by mankind were unconsciously evolved by living things long before the primate made his appearance on the earth. Let us discuss these somewhat in detail.

**Offensive and Defensive Armor.** Protection is a common necessity. Very large numbers of animals and plants, ranging from microscopic unicells to members of the highest groups, develop a covering of one sort or another that serves as armor. In fact, in cell organization the membrane which surrounds the cell-body may be thought of as having a protective use. The skin similarly serves the metazoan, and this at points becomes highly specialized for offense and defense. The armadillo and the turtle illustrate the use made of bony and horny carapaces. Spines such as those of the hedgehog and the porcupine are equally effective. Hair and feathers, especially when long and heavy, defend the skin from mechanical injuries as well as from excessive heat and cold. Innumerable shell-fish, starfish, sea-urchins, many worms, most crustaceans and insects, and in fact some members of almost every group of animals would be classed as armored. Not only do we find many forms of protective coverings, but instruments of offense and defense as well, among which may be mentioned horns, claws, hoofs, fangs, tusks, stings, and even batteries for giving electric shocks. Whether these may not all be used as much for the injury or capture of prey as for defense from enemies is a

question we need not discuss here. It is as true in wild life as in football that a good offense is the best defense; and it is also as true of lower organisms as it is of mankind that much of the equipment needed for warfare is also quite as useful for maintenance.

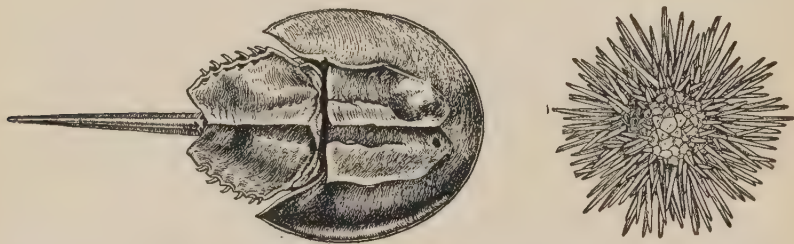


Figure 65. Protective Armor. The Horseshoe Crab and the Sea Urchin.  
(From Gruenberg.)

**Protective Coloration and Camouflage.** Many kinds of animals are colored and marked in such a way that they merge into their background. Thus, animals of the desert are commonly sand-colored; tree-living animals are commonly green or bark-colored; many insects have a pattern like that of lichen-covered trunks and branches of trees; many aquatic forms are transparent; arctic forms are frequently white, at least during the winter. Another type of camouflage is that brought about by countershading. Most fishes are dark above and light below, with a shading off of one into the other. When seen from above, the dark upper surface is invisible against the dark bottom; when seen from the bottom the light surface is in shadow and is relatively inconspicuous against the surface water and sky; and when seen from the side the effect is likewise one that promotes invisibility. Birds and mammals also commonly exhibit countershading. The use of contrasting and sometimes brilliant colors arranged in broken patches and bands may appear conspicuous when the animal is stationary or in a glass case, but in the mixed light and shadows of a forest, at a considerable distance, or when in rapid movement, this serves to conceal the animal most effectively. Sometimes broken patches of light and dark merely serve to break up main contours and make the animal appear like something utterly different from its true self; and this is the essence of camouflage.

**The Use of False Insignia and Flags.** There are some very striking cases of the use of color to deceive or to allure prey. Thus in India there is an insect, a Mantis, which looks extremely like an open orchid blossom. Insects fly into this animated death trap when in search of nectar. Another case of the use of false insignia is that of a spider which so closely resembles the excreta of a bird that butterflies and other insects accustomed to feed upon such excreta frequently alight upon and are captured by the camouflaged spider; the sun-dew and Venus fly-trap hold out an attractive appearance of food which proves to be a fatal entanglement. Not only are false insignia used to attract other animals



Figure 66. The Praying Mantis. The animal lies in wait for its prey, with the front legs raised in a manner suggesting the attitude of prayer. It catches small insects with its strong front legs. Larger species, living in the tropics, have been known to kill small birds. (From Gruenberg.)

which are made the victims of deception, but the same method is used by certain plants which thereby obtain the cooperation of animals to do useful work. An outstanding example is that form of fungus called the stink-horn. It exudes an odor resembling carrion. This attracts insects in search of this kind of food, they are induced to walk over the pasty, spore-bearing surface and carry away the spores to places favorable to reproduction of the species.

**The Use of Poisonous and Nauseous Gases.** The skunk, the polecat, and in fact, all members of that family of carnivora, emit a nauseous odor that has a high protective value. A good many insects also, including the bombardier beetle and the caterpillar larvae of several species of butterflies, protect themselves by nau-

seous odors. The turkey buzzard, wounded or at bay, resorts to a similar device. When attacked or in danger, this bird of carrion will vomit—and the regurgitated food in a state of advanced decomposition is so offensive to mankind and certain other animals that they are turned away.

**Reconnoiter and Espionage—Means of Learning of Potential Danger.** The extraordinarily keen senses of some animals serve to enable them to gain information about the approach of potential danger before the danger comes near enough to be a real

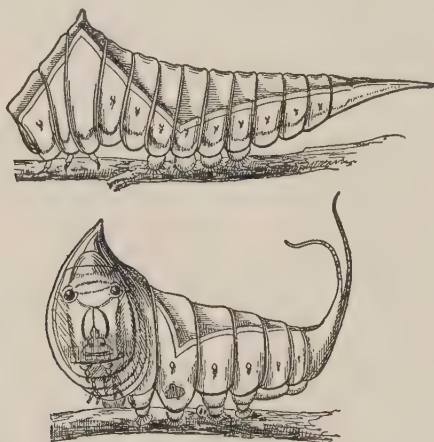


Figure 67. Larva of the Puss Moth (*Cerura*) Showing Terrifying Appearance. The upper figure shows the larva as it appears when undisturbed; lower figure, when disturbed. (From Jordan and Kellogg, after Poulton.)

threat. Thus, many mammals can scent the presence of enemies if borne on the wind. An experienced deer hunter will always travel against the wind so that his scent will not serve as a tell-tale to his quarry. In many, the hearing is exceptionally keen and by turning the trumpet-shaped ear lobe in various directions they can locate the danger with some precision. The behavior of birds and other animals, especially certain cries, comes to be instinctively responded to as warnings.

**The Use of Danger Signals.** The white stripes of the skunk, the brilliant contrasting bands of color on the venomous coral snake, the bright red of the poisonous fire-bellied toad, and

thousands of other similar markings are interpreted by some authors as examples of warning coloration. A newer interpretation of "warning" markings is that contrasting color patterns act as camouflage and are therefore not conspicuous. Unless they are conspicuous they would not warn. But the chief reliance of animals is the oral danger signal—some cry or characteristic sound recognized by other members of the species as a call for attention or a signal for flight. In certain cases these sounds are calls which arouse the fighting instinct instead of fear.

**Regulative Mechanisms.** Wherever there is motorization, there is need for regulation. Dynamic mechanism without means of control is destructive of order—and consequently destructive of the very conditions on which life depends. To illustrate this by reference to everyday experience: Let us consider what would be the result of using a high-power motor vehicle without a system of devices by means of which every stroke of the cylinder, every turn of a wheel, could be kept in control. Apply the same thought to a human organization—an army. What would an army be without discipline? Biological law is a scheme of order established and maintained in the operation of vital mechanisms. There is the same need for regulative devices in a "cell-state" that there is in a body-politic. We see the effects of lack of control in epileptics, semi-paralytics, and persons affected by such diseases as *locomotor ataxia*.

**Mechanism of Coordination.** Continuity of life depends quite as much on devices by which a species of organism may be protected from internal strains and struggles as it does on devices developed to protect it from violence from without. Among living things, as with human inventions, motor mechanisms and means of coordination and control have grown up together. On its purely mechanistic side the nervous system is a marvelous controlling and coordinating device. Both functionally and structurally it presents two quite differing systems that are interrelated. Biologically, the older of the two is that which automatically coordinates and controls the vital functions discussed below—the sympathetic nervous system. Alongside of and supplementary to this is the spinal motor system. This is not the place to do more than to point to the fact that the nervous system is to be thought of as

one of the complements of protective devices—just as a line of communication is necessary to war, and as police surveillance and regulation are necessary to the orderly conduct, human cooperation and community life, when on a peace footing. The nervous system as such is the subject of a later chapter.

### Mechanisms for Carrying on Vital Functions

Strictly speaking, vitality or vital energy is the result of functions that take place in the cell—collectively known as metabolism. Vital functions as here discussed are those which are necessary, but not directly related to metabolism. They are incidental. They are the service organs that supply the cells with the material basis of vitality. They are called vital organs for this reason—they are the mechanisms for carrying on processes by which needed supplies are obtained and distributed and waste is eliminated. Vital functions in this sense are those by means of which conditions are produced within the organism that result in chemical and physical change—with a release of heat, electricity, vitality. In one sense, development of vital energy, the end effects of which are secretion, motorization, repair of structures, enlargement (growth), etc., is life. The mechanisms directly used in producing the conditions by which this energy is released are called “vital” to distinguish them from those discussed above as “protective”—and those which follow as “augmentive” and “reproductive.”

**Organs of Expropriation.** Not only must there be specialized mechanisms for self-protection suited to each species, but each must also have means for self-maintenance; and as has already been said, very definite mechanical means must be provided for expropriating from nature the things which, to the organism, are “goods”—things that are useful in the circumstances in which the organism finds itself. The development of such mechanisms is among the specific adaptations. Deeply buried in the sand for protection, the sea-clam employs a syphon (two feet long in some individuals of one species on the Northwest coast) through which the sea water, laden with small organisms, may be sucked in; similarly, out of the structure of the roof of the mouth of a whale is developed a process resembling a “whalebone” brush,

used by it for gathering food as it moves through the water; the humming bird has come to have a characteristically long bill by means of which it can reach into the nectar tube of a flower; the lobster comes to be right-handed or left-handed, one adapted as a grappling tool (being especially equipped for clinging to weeds and grass for anchorage), the other for grabbing and crushing its victim; the hog has a tough, callous snout for "rooting." The list of these specialized tools or instruments for carrying on what may be thought of as the extractive industries in the animal world may be indefinitely enlarged; in fact, each species may be said to have developed its own peculiar mechanical arrangements for performing this function.

**Mechanisms for Expropriation of Solids and Liquids.** For convenience, we may consider separately those mechanisms that expropriate solids and liquids from those that expropriate oxygen or other needed gases. In general, the mouth and all of its accessory parts are primarily concerned with food expropriation. In the crabs and lobsters no less than six or seven pairs of appendages are termed "mouth parts" because they cooperate in the capture and preparation of food for swallowing. In birds and turtles the beak, in the elephant the trunk, in the ant-eater the long snout and slender sticky tongue, in most vertebrates the teeth, are used mainly for food capture and food preparation.

**Mechanisms for Expropriating Oxygen.** There are three main types of respiratory mechanisms; gills, air-tubes (tracheæ) and lungs. Gills are used for extracting oxygen dissolved in water and are therefore characteristic of aquatic organisms. The gill is essentially a finely divided, thin-walled extension of some portion of the body surface provided with an abundant supply of blood. The oxygen in the water passes through the thin walls of the bronchial tissue and is taken up by certain substances in the blood that have a particularly strong affinity for oxygen. Tracheae are thin-walled tubes that communicate with the exterior. In insects and myriapods these tubes carry oxygen all over the body, bringing it very close to the ultimate consumers, the individual tissue cells. Lungs are characteristic of land vertebrates. They are elaborately branched, thin-walled sacs developed from an out-pouching of the pharynx. Air is taken in by expand-

ing the lungs and expelled by compressing them. The inner surface of the lung is wet and dissolves some gaseous oxygen. This, in turn, passes through the thin membrane and is absorbed by the haemoglobin, the red substance in the red blood corpuscle. These corpuscles travel to every part of the body and give up their loosely held oxygen to any tissues having a greater affinity for it than has the haemoglobin.

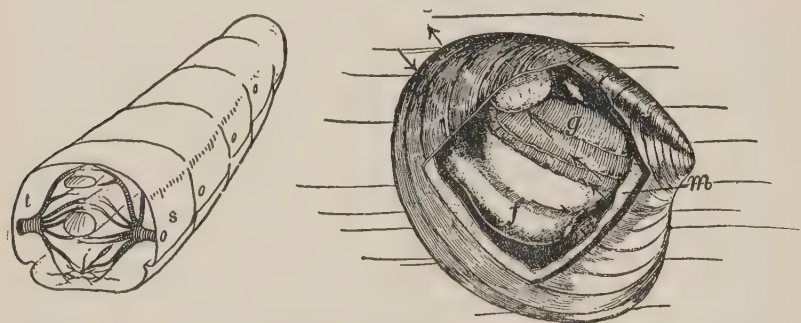


Figure 68. Organs of Breathing in Insects and Clams. In insects (left) the spiracles, *s*, open into the trachea, *t*, which branch repeatedly and bring air to the tissues. In clams the water direction of water flow is indicated by the arrows—forward toward the foot, *f*, up past the mouth, and backward over and between the gills, *g*. The water is kept in motion by cilia on the body and on the mantle, *m*. (From Gruenberg.)

**Digestion.** Digestion is a process of conditioning or “processing” of materials expropriated. If an automobile had a mechanism for refining crude petroleum, it would be able to do what is done by organisms by means of those specialized parts called organs of digestion. They are a laboratory in which substances expropriated from nature are “reduced.” Organisms take food materials from nature quite as complex as petroleum. These materials are passed through an intricate series of physical and chemical transformations. The ingredients that have food value are separated out and changed into a state which makes them available for storage and final use in the energy-releasing processes mentioned above.

**Organs for Physical Reduction.** The first step in digestion is one of dividing the mass into smaller pieces in order to expose all parts to chemical action. In some organisms (the lobster

and crab), the process of maceration is done by appendages outside of the mouth, but in most vertebrates this process is done either in the mouth or farther down the alimentary tract—as in a chicken. In many mammals, especially the ruminants, coarse foods are ground up by teeth or grinding parts adapted to the

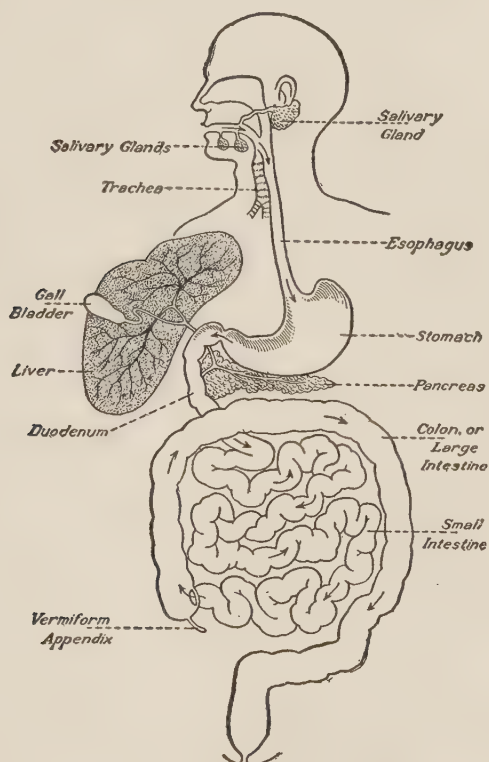


Figure 69. The Digestive System. (From Peabody and Hunt.)

work to be done. In birds, which have no teeth, the food is commonly passed to a muscular grinding mill, a gizzard, where it is ground up into a pulp before it passes to the true stomach. The alimentary canal is a convenient mechanism for conducting food from process to process.

**Organs of Chemical Reduction.** Thus, after food is masticated, it is swallowed by a muscular tube, the œsophagus. It then

passes to the stomach where it is worked upon by *gastric juice*, a chemical substance composed of hydrochloric acid and two enzymes, rennin and pepsin. The acid serves to activate the enzymes, which respectively coagulate milk and break down proteins into peptones and proteoses, soluble substances that may be taken into the blood stream. When food which has not been taken into the blood stream by the stomach passes from that organ into the small intestine, it is further acted upon by *pancreatic juice*, a substance secreted by a gland known as the *pancreas*. The pancreatic juice contains three enzymes known as trypsin, amyllopsin, and steapsin. These all have different functions, trypsin completing the digestion of proteins begun in the stomach, amyllopsin splitting up the more complex carbohydrates such as starch into simple sugars, steapsin splitting up fats into glycerol and fatty acids. Further along the food canal, another secretion, bile, from the liver, encounters the food residue and helps to complete the digestion of fats. The small intestine also secretes enzymes that help to extract the last of the valuable products from the food mass, and it is in this region of the canal that much of the processed food is absorbed and transferred to the chyle ducts and the blood stream.

The process of digestion serves the organism by separating ingredients with high energy potential from those with low energy potential. The high potentials are taken into the blood stream, while the low potentials ("tailings" of the mill one might call them) are carried on into the large intestine and cast out of the organism at the vent.

**The Mechanism of Assimilation and Storage of High Potentials.** The chief process by means of which the food elements necessary for the upkeep of the mechanism are separated from the "tailings" and gotten into the circulation is one known as *osmosis*. This is a process involving the passage of dissolved substances through membranes. When once a part of the blood stream, the food materials may be either used up quickly (in dynamic activity, in growth, or in maintaining the bodily temperature), or else they may be stored for future and emergency uses. Stores of food reserves are put away in the form of fat, which may be widely distributed over the body, in the form of glycogen in the liver,

in the marrow of the bones, and in some connective tissues. In case of food shortage or in wasting diseases these stored reserves may be taken up into the circulation and transported to the most important vital organs.

**The Mechanism in Which Vital Energy Is Developed—The Cell as an Organ of Combustion of High Potentials.** After the relatively simple food substances carried by the blood stream reach

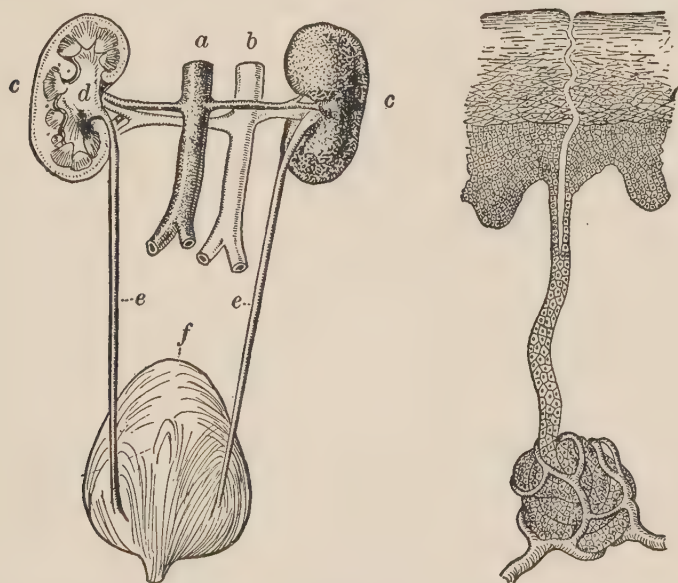


Figure 70. Organs of Excretion—Kidneys and Bladder (left) and a Sweat Gland (right). *a*, the main artery and *b*, the main vein, in the abdominal cavity, giving off branches to the kidneys, *c*, *c*; *d*, the funnel-shaped cavity in which waste fluid is gathered by the gland action of the kidney; *e*, *e*, tubes leading from the kidney to the bladder, *f*. The left kidney is represented in longitudinal section. (From Gruenberg.)

the ultimate consumers, the tissue cells, they are absorbed by these units and the absorbed substances are re-synthesized into more of the characteristic protoplasmic ingredients of each kind of cell. This makes it possible for cells to oxidize their proteins, carbohydrates, fats, and other materials without danger of irreparable loss. The final step in food utilization, then, is this breaking down of high potentials within the individual cells. This process means

not only a formation of simpler substances with lower potential, but it means the release of energy for all sorts of vital needs.

**The Mechanism of Elimination of Low Potentials.** As a by-product of this chemical transformation, many kinds of materials are released that are of no use and must be eliminated. There is an elaborate mechanism for getting rid of these by-products of metabolism. The kidneys play an important rôle in eliminating from the blood stream much of the dissolved materials. The skin excretes through the sweat glands some materials of a similar nature.<sup>1</sup> The liver takes up other excess materials and transforms them into less harmful materials that may be excreted in the form of bile. Excess salts and excess water are eliminated both through the kidneys and through the sweat glands. Carbon dioxide, a product of the combustion of nearly all protein materials, is eliminated largely through the lungs, though both sweat glands and kidneys help in this process.

**The Mechanism and Function of Circulation.** Circulation is a canalization phenomenon. Because the bodies of larger animals are bulky and many of the tissues are far from the source of supply of solid, liquid and gaseous raw materials, it is necessary to connect up the outlying regions by means of a system of supply canals. The system of circulation consists of a one-way circuit in which there are no cross currents or back waters. The blood starts from the left ventricle of the heart which, by contraction, sends the stream through the main arterial trunks. These divide and re-divide, finally terminating in the finest ramifications, called capillaries. These capillaries reach the ultimate life units, which take some materials from the blood and give back to it other materials. Capillaries unite, then, into small veins, these into larger veins, and the latter into the great venae cavae or main venous trunks. Finally, all these unite into a single venous trunk which enters the right auricle. The impure blood then passes to the right ventricle, is pumped from there into the lungs, and, after being distributed through the lung capillaries, returns to the left auricle, and the circuit is complete.

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<sup>1</sup> Its excretory function is less than it was formerly thought to be.

**The Blood as a Carrier.** The blood itself is a complex fluid carrying certain solid bodies known as corpuscles. The red corpuscles contain a material known as haemoglobin which has a purplish color. When it unites in the lungs with oxygen, it becomes oxyhaemoglobin, a bright red substance. After giving up

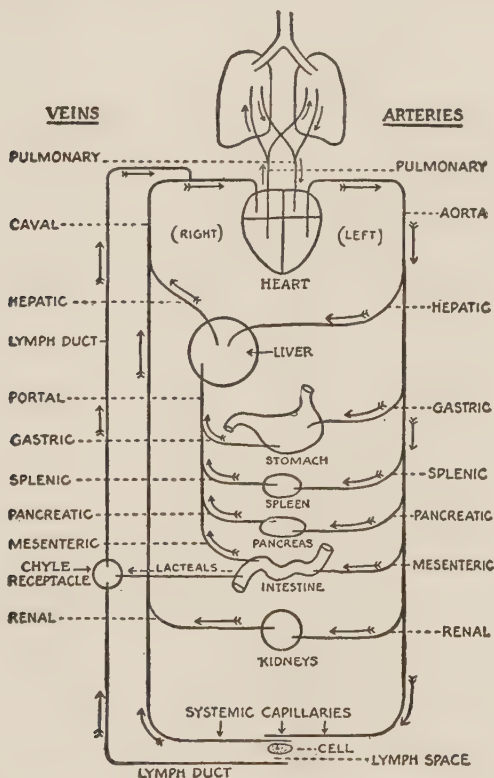


Figure 71. Circulation of the Blood—Diagrammatic. (From Moon.)

its oxygen to the tissues, it again loses its bright red color. We may look upon the red blood corpuscles as common carriers, transporting oxygen from the source of supply to the consumer. The white corpuscles are police and scavengers, combined. It is their duty to pick up solid detritus, whether living or dead. They feed upon the broken fragments of dead cells worn out by use, and also destroy bacteria and other foreign micro-organisms that have

succeeded in entering the blood stream. They are so devoted to their duty that they often lose their lives in combat with foreign organisms; for the pus that accompanies infections is composed largely of the dead bodies of these defenders of health.

**Organs of Growth.** When the appropriation of energy containing materials exceeds its expenditure in mechanical or other

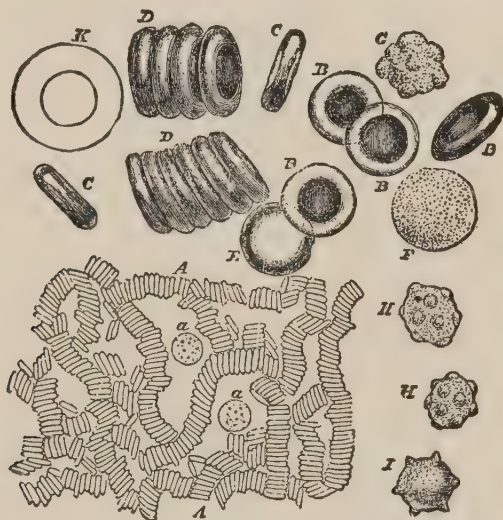


Figure 72. Blood Corpuscles. *A*, magnified about 400 diameters. The red corpuscles have arranged themselves in rouleaux; *a, a*, colorless corpuscles; *B*, red corpuscle more magnified and seen in focus; *E*, a red corpuscle slightly out of focus. Near the right-hand top corner is a red corpuscle seen in three-quarter face, and at *C* one seen edgewise. *F, G, H, I*, white corpuscles highly magnified. (From Moon, after Martin-Fitz.)

work, these materials accumulate in the individual cells of the body, and as a consequence the cells increase in size. This constitutes the simplest phase of growth. The size of the individual cells, however, has its very distinct limits, and this for several reasons. For carrying on the necessary exchanges between the cell body and the external media a considerable surface is necessary. When the mass increases, the surface does not increase in proportion, and very shortly the surface is too small for the mass. The way in which nature overcomes this barrier to growth is through the process of cell division. When a cell grows as large

as it can and can get no larger it divides into two daughter cells half the size of the mother cell. Thus the proper surface-mass relation is restored, and this can be repeated as often as necessary up to the limit of size that the organism is capable of reaching.

**Reproduction Mechanism.** All of the adaptive mechanisms just considered have to do with self-protection and self-maintenance, but it is equally important for life to increase and multiply and for the life stream to continue to flow forward and to broaden. No organism is capable of living forever. Some live for thousands of years; others only for hours, or even minutes. What-

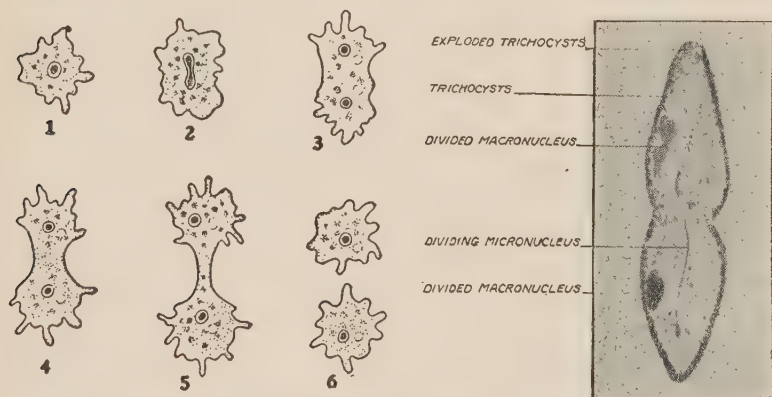


Figure 73. Reproduction by Fission. Amoeba (left) and Paramecium (right). (From Moon and from Calkins.)

ever may be the life span, the individual is mortal and if posterity is to be provided for, new individuals must be reproduced out of materials provided by old individuals.

**Types of Reproductive Devices.** There are numerous types of reproductive devices. The simplest is known as *binary fission*, or merely a division of the parent of low order into two parts, each of which grows into an organism like the parent. Fission is common in both unicellulars and multicellulars. We find it in bacteria, in amoeba, in worms of many kinds. It is also found in the embryonic development of higher orders—even in the embryos of man when duplicate twins are formed. *Budding* and *slipping* are common processes of reproduction among lower

animals and plants. These processes consist merely of the cutting off of outgrowths of the parent body either automatically or through the action of severing agents. *Sporulation* is a common method found in lower plants and in many parasitic unicellulars. *Germinal reproduction* is by far the most successful and the favorite method of maintaining the life stream. It consists of

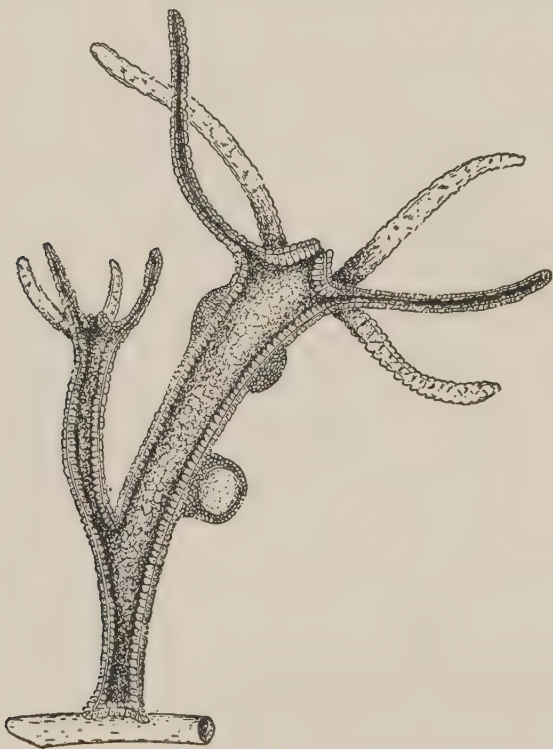


Figure 74. Reproduction by Budding in the Hydra. (From Calkins.)

the setting aside of certain cells, the germ cells, for the one and only function of reproduction. Such cells, when freed from the parent body, acquire independence and are able to grow and divide in such a way that they are able to reproduce the image of the parent in all essential features. Far more commonly than not, germ cells are of two kinds, *eggs* and *sperms*. Neither the egg alone (except in parthenogenesis) nor the sperm alone can develop,



Figure 75. Reproduction by Budding in Yeast Plants. (From Gruenberg.)

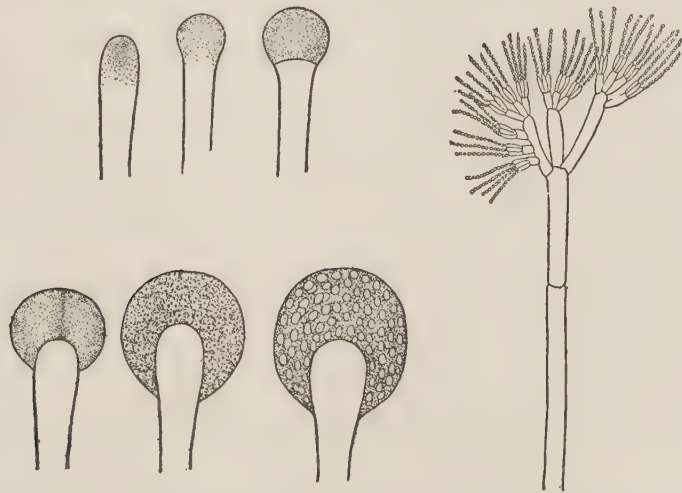


Figure 76. Reproduction by Spores. In the black molds (left), the spores are formed by the repeated division of the protoplasm in an enlarging cell at the end of a thread. When mature, the inclosing wall breaks, and the spores are scattered. In the blue molds (right), the spores are formed by the successive separation of terminal portions of the branched threads. This is a type of fungus used in ripening Camembert cheese. (From Gruenberg.)

but they must unite to form a dual cell or *zygote* before the process of embryonic development can take place. The germ cell is not only the means of continuing life from generation to generation, but it is also the hereditary bridge between successive generations and thus the means for conserving types of successful mechanisms and preventing their loss when individuals die.

**Growth, Development, and Reproduction as Related Processes.** Growth, development and reproduction are very closely allied processes. So long as cell division and differentiation involves no breaking away of elements from the central control of the individual, we may call the processes growth and development. But as soon as any part attains independence and loses its physiological coordination with the parent body, reproduction takes place. Growth may be thought of as mere increase in size, whether it is of cells or of tissues or organs. Development, however, involves not merely growth, but also all processes that are involved in the attainment of definite body forms and specializations of different cells and tissues. In general, development is growth plus differentiation.

### QUESTIONNAIRE WITH READING REFERENCES

1. Discuss life as a continuing stream. In what sense may the "stream of life" be considered as continuing from the beginning—and branching or widening out as it finds new channels by way of differentiation of species?

R. Chambers, in *General Cytology* [Univ. of Chicago Press, 1924], Structure and viscosity of cytoplasm, pp. 241-251; Existence in protoplasm of a differentiated cortex and interior, pp. 251-262; Diffusion of injected substances through the cytoplasm, pp. 262-265.

L. W. Sharp, *Introduction to Cytology* [N. Y.: McGraw-Hill, 1921], p. 15.

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E. B. Wilson, *The Cell in Development and Heredity* [N. Y.: Macmillan, 1925, 3d ed. rev.], pp. 57-78.

R. Pearl, *The Biology of Death* [Philadelphia: Lippincott, 1922], Ch. II, Conditions of cellular immortality, pp. 51-78.

2. Discuss the protoplasmic mechanism as a structure adapted to facilitate and perpetuate the streaming process. What is meant by the "streaming process" that goes on in non-canalized protoplasmic structure?

M. H. Jacobs, in *General Cytology*, Sec. III, Permeability of the cell to diffusing substances, pp. 97-156; R. Chambers, Viscosity changes in the amoeba, pp. 276-283.

B. M. Duggar, *Plant Physiology* [N. Y.: Macmillan, 1922], Ch. II, The plant cell, pp. 15-34.

H. E. Jordan and J. S. Ferguson, *Text-book of Histology* [N. Y.: Appleton, 1916], pp. 10-14.

R. S. Lull, *Organic Evolution* [N. Y.: Macmillan, 1926], see index "Protoplasm."

W. A. Locy, *Biology and Its Makers* [N. Y.: Holt, 1908, 3d ed. rev.], Ch. XII, Protoplasm the physical basis of life, pp. 259-275.

J. Y. Bergen, *Foundations of Botany* [Boston: Ginn, 1901], Ch. XII, Protoplasm and its properties, pp. 178-185.

S. C. Brooks, in *Am. Jour. of Botany*, Vol. III, 1916, Studies in Exosmosis, pp. 483-492; Study in permeability by the method of tissue tension, pp. 562-570.

3. Discuss "canalization" of the streaming process as structural specialization in the interest of "adaptation."

Duggar, *op. cit.*, Ch. V, Transpiration and water movement, pp. 84-115.

H. Bergson, *Creative Evolution* [N. Y.: Holt, 1911, Mitchell trans.], see index "Canalization."

W. F. Ganong, *The Living Plant* [N. Y.: Holt, 1922], Ch. VII, Ways in which plants draw into themselves the various materials they need, pp. 165-197; Ch. VIII, Ways in which substances are transported through plants and finally removed therefrom, pp. 198-223.

4. Discuss progressive evolution in terms of adaptation of mechanism—as changing types of "species" of the mechanistic arrangements to perpetuate the stream of life and to broaden its flow.

Newman, *op. cit.*, Ch. XXXVI, Evidences of evolution, pp. 408-431.

Lull, *op. cit.*, Ch. XIX, Cursorial and fossorial adaptation, pp. 294-315; Ch. XX, Aquatic adaptation, pp. 316-336; Ch. XXI, Scansorial adaptation, pp. 337-346; Ch. XXII, Volant adaptation, pp. 347-367; Ch. XXIII, Cave and deep-sea life, pp. 368-392; Ch. XXIV, Desert adaptation, pp. 393-408; Ch. XXV, Fossils: their nature and interpretation, pp. 409-420; Ch. XXVI, Cephalopods, pp. 421-437; Ch. XXVII, Insects, pp. 438-459; Ch. XXVIII, Origin of vertebrates, pp. 460-476; Ch. XXIX, Emergence of terrestrial vertebrates, pp. 477-496.

Bergson, *op. cit.*, see index "Evolution, animal," also "continuity of."

5. On what does the continuity of the streaming process in the individual organism depend? Discuss in terms of behavior adaptation of mechanism.

Pearl, *op. cit.*, pp. 26-50.

C. Darwin, *The Origin of Species* [N. Y.: Appleton, 1901], Ch. III, Struggle for existence, pp. 75-96.

H. S. Jennings, *Behavior of the Lower Organisms* [Columbia Univ. Press, 1915], Ch. XVIII, Analysis of behavior, pp. 300-313; Ch. XIX, Development of behavior, pp. 314-327; Ch. XX, Relation of behavior in lower organisms to psychic behavior, pp. 328-337; Ch. XXI, Behavior as regulation and regulation in other fields, pp. 338-350.

G. Haberlandt, *Physiological Plant Anatomy* [London: Macmillan, 1914, Drummond trans. from 4th ed.], Ch. I, Cells and tissues of plants, pp. 14-72.

6. On what does the continuity of the species depend? Discuss in terms of adaptation of mechanism.

Lull, *op. cit.*, Ch. XIV, Recapitulation, racial old age, extinctions, pp. 213-228; Epilogue, The pulse of life, pp. 687-691.

Bergson, *op. cit.*, see index "Evolution, continuity of," also "Evolution and duration."

Darwin, *op. cit.*, Ch. IV, Natural selection; or the survival of the fittest, pp. 97-163.

J. M. Macfarlane, *The Causes and Course of Organic Evolution* [N. Y.: Macmillan, 1918], Ch. IX, Law of proenvironment, pp. 205-242.

7. What are four general classes of mechanistic adaptations on which the continuity of life of the species depends? Discuss in terms of mechanism.
8. Distinguish between devices for protection, maintenance, development and reproduction.
9. Why are all organisms as living things particularly subject to attack and injury from violence? Discuss in terms of the need for expro-

priation and unbalancing of "an established order" when conditions are brought about which change potential into kinetic energy.

Newman, *op. cit.*, Ch. IV, Nature and manifestations of life, pp. 40-48.

10. Thinking of life as a manifestation resulting from the release of energy by a process of upsetting "systems" of order, and conceiving of the problem of living as one of taking advantage of or producing upsets which may be availed of by the organism, how is this conception related to the need for protection? May it be said that life's mechanisms in the nature of things must always be in peril?
11. Name the most general classes of protective devices evolved by nature to prevent impairment of vital mechanisms from violence.  
J. McFarland, *Biology, General and Medical* [Philadelphia: Saunders, 1918, 3d. ed.], Ch. XIV, Parasitism, pp. 313-349; Ch. XV, Infection and immunity, pp. 350-386; Ch. XVI, Mutilation and regeneration, pp. 387-405.  
Haberlandt, *op. cit.*, Ch. III, Dermal system, pp. 100-149; Ch. IV, Mechanical system, pp. 150-213.  
Newman, *op. cit.*, pp. 375-379.
12. What may be included in protective body equipment?  
Haberlandt, *op. cit.*, Ch. III, Dermal system, pp. 100-149; Ch. XI, Motor system, pp. 542-570.  
F. E. Beddard, *Mammalia* [London: Macmillan, 1920, Cambridge Natural Hist., Vol. X, Harmer and Shipley, eds.], pp. 111, 149, 184, 190, 222, 231, 255-258, 498-500.
13. Give illustrations of defensive armor evolved by nature in plant and animal species.
14. Give illustrations of temporary defensive coverings.  
Newman, *op. cit.*, p. 124.
15. Give illustrations of body weapons of offense and defense evolved by nature.  
Beddard, *op. cit.*, p. 14.  
Newman, *op. cit.*, pp. 375-379.  
W. S. Berridge, *Marvels of the Animal World* [Boston: Small, Maynard, 1922], Ch. X, Offensive and defensive weapons of animals, pp. 159-179; Ch. XIII, Poisonous animals, pp. 204-227.
16. Give illustrations of the offensive and defensive use of poisons.
17. Give illustrations of the offensive and defensive use of electric charges.
18. Give illustrations of the use of sounds and appearances to terrify an enemy.  
D. S. Jordan and V. L. Kellogg, *Evolution and Animal Life* [N. Y.: Appleton, 1908], Terrifying appearances, p. 418.
19. What is meant by camouflage? Give illustrations of protective coloration and configurations.  
Lull, *op. cit.*, Ch. XV, Coloration and mimicry, pp. 229-247.  
Jordan and Kellogg, *op. cit.*, Ch. XIX, Color and pattern in animals, pp. 398-425.  
A. W. Weyssse, *Synoptic Text-book of Zoology* [N. Y.: Macmillan, 1904], pp. 462-466.  
R. R. Wallace, *Darwinism* [London, Macmillan, 1923], Ch. VIII, Origin and uses of color in animals, pp. 187-231.  
G. H. Thayer, *Concealing-Coloration in the Animal Kingdom* [N. Y.: Macmillan, 1909], whole book, 260 pp.

20. Give illustrations of use of false insignia and flags evolved by nature and used by organizations.

Wallace, *op. cit.*, Ch. IX, Warning coloration and mimicry, pp. 232-267.

21. Give illustrations of the emission and use of offensive and nauseous gases.

Beddard, *op. cit.*, pp. 12, 13.

22. What is the relation of sense organs to protective adaptation?

23. Give illustrations of reconnoiter and espionage or means whereby the individual organism may learn of potential danger.

24. Give illustrations of insignia as means whereby one member of a species may warn others of need of caution or flight.

Jordan and Kellogg, *op. cit.*, Directive coloration, p. 419; Recognition marks, p. 420.

25. Give illustrations of protective devices to prevent the cutting of the basic supplies, both in plants and animals.

J. M. Coulter, C. R. Barnes, and H. C. Cowles, *Text-book of Botany* [N. Y.: American Book Co., 1910, 2 vols.], Vol. I, p. 388.

E. Warming, *Ecology of Plants* [Oxford: Clarendon Press, 1909], Ch. XXXII, Storage of water by land—plants, pp. 119-126; Ch. XCVIII, Weapons of species, pp. 366-368.

26. Give illustrations of regulative devices for control over individual and group movement.

Jordan and Kellogg, *op. cit.*, Ch. XX, Reflexes, instinct, and reason, pp. 426-450.

Weyssse, *op. cit.*, Ch. XIII, Animal behavior, pp. 480-493.

Haberlandt, *op. cit.*, Ch. XII, Sensory system, pp. 571-631; Ch. XIII, Stimulus-transmitting system, pp. 632-646.

27. Give illustrations of artificial protective devices used by (a) unicells; (b) lower metazoans; (c) insects; (d) lower vertebrates; (e) warm-blooded animals.

Newman, *op. cit.*, Ch. XXXII, 'Adaptations, pp. 370-389.

28. Discuss the mechanism or means of coordinating the various cooperating members of an organism or group; distinguish tropism, instinct and intelligence.

Darwin, *op. cit.*, Ch. VIII, Instinct, pp. 319-365.

Coulter, Barnes, and Cowles, *op. cit.*, Tropisms, pp. 432, 458.

Jennings, *op. cit.*, Pt. III, Analysis of behavior in lower organisms, with a discussion of theories, pp. 260-350.

W. H. Howell, *A Text-book of Physiology* [Philadelphia: Saunders, 1924, 9th ed. rev.], Ch. VII, Reflex actions, pp. 139-159.

J. H. C. Fabre, *The Wonders of Instinct* [N. Y., Century, 1918], whole book, 322 pp.

29. What, in terms of social organization, are the devices of man most nearly akin to the organic protective devices?

30. What is the general name or term used to include the functions of maintenance, growth and reproduction in organism, and what are the several classes of "vital" functions included under this title?

Newman, *op. cit.*, pp. 338-339.

31. What are two general classes of expropriative organs?

32. Give a list of organs highly specialized for expropriations of solids and liquids.

Lull, *op. cit.*, Ch. XXXIV, Proboscideans, pp. 577-603.

F. O. Bower, *Plants and Man* [London: Macmillan, 1925], p. 106.

F. O. Bower, *Botany of the Living Plant* [London: Macmillan, 1923], Ch. VI, The root, pp. 80-92; Carnivorous plants, pp. 220-223.

33. Give a list of highly specialized organs whereby animals are able to expropriate or extract oxygen from the air.

Haberlandt, *op. cit.*, Ch. IX, The aerating or ventilating system, pp. 432-484.

Howell, *op. cit.*, Sec. VI, Physiology of respiration, pp. 637-716.

34. What are the highly specialized organs of extraction of carbon dioxide gas from air by plants?

Bower, *Plants and Man*, Ch. II, The green leaf, pp. 12-24.

Haberlandt, *op. cit.*, Ch. VI, Photosynthetic system, pp. 261-301.

35. What is meant by the terms "digestion" and "indigestion"?

Haberlandt, *op. cit.*, Ch. VI, Photosynthetic system, pp. 261-301; Digestive glands, pp. 502-507.

P. G. Stiles, *Nutritional Physiology* [Philadelphia: Saunders, 1915, sec. ed.], Ch. III, The nature and the means of digestion, pp. 28-35.

Howell, *op. cit.*, Ch. XXXIX, Movements of the alimentary canal, pp. 717-740.

36. Confining discussion to the more highly developed animals, what are the specialized organs for the physical reductions of solids expropriated from nature?

Howell, *op. cit.*, Sec. VII, Physiology of digestion and secretion, pp. 717-902.

Stiles, *op. cit.*, Ch. VII, The mouth—swallowing, salivary digestion, pp. 63-69; Ch. VIII, The movements of the stomach, pp. 70-79; Ch. IX, Gastric secretion and digestion, pp. 80-89; Ch. X, The small intestine; its movements, secretions, and digestive processes, pp. 90-99; Ch. XI, The large intestine, pp. 100-106; Ch. XII, The blood, pp. 107-117; Ch. XIII, The circulation, pp. 118-129; Ch. XIV, The absorption of food-stuffs, pp. 130-136.

37. What are the special organs of chemical reduction of solids and liquids expropriated from nature by the more highly developed animals?

A. P. Mathews, *Physiological Chemistry* [N. Y.: Wm. Wood, 1925, 4th ed.], Ch. VIII, Salivary digestion, pp. 330-348; Ch. IX, Digestion in the stomach, pp. 349-398; Ch. X, Digestion in the intestine, pp. 399-465.

Howell, see reference to question above.

38. What are the specialized mechanisms of assimilation and storage of substances extracted which have a high potential energy and may be used for carrying on the vital processes?

Mathews, *op. cit.*, Ch. XI, Absorption, pp. 466-473.

Bower, *Plants and Man*, Ch. I, General outlook, pp. 1-11; Ch. XIII, Kitchen garden, pp. 148-158; Ch. XIV, Dessert fruits, pp. 159-170; Ch. XV, Cereal grains, pp. 171-183; Ch. XVI, Vegetable foods, pp. 184-193.

Haberlandt, *op. cit.*, Ch. V, Absorbing system, pp. 214-260.

Howell, *op. cit.*, Ch. XLIV, Physiology of the liver and spleen, pp. 816-837.

39. What, in terms of social organization, are the devices of man most nearly akin to the organic mechanisms of expropriation, digestion, assimilation and storage of high potentials?

40. What is the mechanism in which vital energy is developed—the process by which substances of high potentiality are transformed into low potentials?

Macfarlane, *op. cit.*, Ch. II, Relations and transformations of energy during the evolution of matter, pp. 21-47; Ch. III, Relation of inorganic to organic bodies,

pp. 48-67; Ch. IV, Energies of the organic world—the biotic, the cognitive, the cogitic—and their relation to organisms, pp. 68-96.  
 W. J. Osterhout, *The Nature of Life* [N. Y.: Holt, 1924], Ch. VI, Metabolism, pp. 45-74.  
 Haberlandt, *op. cit.*, Ch. I, The cells and tissues of plants, pp. 14-72.  
 Bower, *Botany of the Living Plant*, Ch. III, The living cell, pp. 29-37.

41. What are the mechanisms for the elimination of the resulting low potentials as "waste"?

Macfarlane, *op. cit.*, p. 521.  
 Mathews, *op. cit.*, Ch. XVIII, Excretions of the body, pp. 724-813.  
 Haberlandt, *op. cit.*, pp. 521-539.

42. What are the mechanism and function of circulation?

Mathews, *op. cit.*, Ch. XII, The circulating tissue, the blood, pp. 474-575.  
 Haberlandt, *op. cit.*, Ch. VII, Vascular or conducting system, pp. 302-394.

43. In terms of social organization what are the devices of man which perform for communities a function similar to that of the circulatory system?

44. Discuss the circulatory system and the blood current as a common carrier and the several organs and the cells of the body as the patrons that are "served" by the system.

Newman, *op. cit.*, pp. 180-192.  
 Haberlandt, *op. cit.*, Ch. VII, Vascular or conducting system, pp. 302-394.  
 Mathews, *op. cit.*, Ch. XII, The circulating tissue, the blood, pp. 474-575.

45. What is the relation of the vital organs to the "motor system" and to the "neuro-controlling system"?

Haberlandt, *op. cit.*, pp. 72, 73.  
 Newman, *op. cit.*, p. 188.

46. What is meant by growth? How is growth carried on by an organism?

Newman, *op. cit.*, pp. 44, 45.  
 Haberlandt, *op. cit.*, Ch. II, Meristematic tissues, pp. 73-99.  
 Bower, *Botany of the Living Plant*, Growth, pp. 130-135.

47. What are the several types or modes of reproductive devices?

Newman, *op. cit.*, Ch. XXVII, Modes of reproduction, pp. 305-319.  
 McFarland, *op. cit.*, Ch. VIII, Reproduction, pp. 169-198.  
 Bower, *Botany of the Living Plant*, Ch. XIII, Vegetative propagation, pp. 224-233; Ch. XVIII, Embryo and the seed, pp. 290-299.

48. How are growth, development and reproduction related as processes?

Newman, *op. cit.*, pp. 44-47.

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## CHAPTER XIX

### NATURE'S DEVICES FOR ASSURING ABUNDANCE \*

**Two General Types of Solutions.** In nature, two general types of solutions of the problem of how best to attain abundance of life are found: (1) adaptations of the structure and functions of the individual organism which add to efficiency in solitary life; and (2) adaptations favorable to mutual aid and other forms of cooperation. This latter means, of course, adaptations which add to the facility with which the structure and action systems of organisms may be combined. And if the combination survives, it means that it is biologically advantageous to the several related individuals that constitute a group. It is to this second type of adaptation that consideration is chiefly given here.

**Adaptations Favoring Efficiency in Solitary Living.** In the previous chapter, we have seen how individuals as organisms protect their own mechanisms, how they maintain their efficiency through the development of specialized organs for carrying on vital functions; how they reproduce new individuals after their kind. For the purpose of considering this class of adaptations, each organism was described as a thing apart—as a mechanism evolved by nature, adjusted in its working parts for developing, expending, and maintaining vital energy. When pursuing this interest, attention is focused on the adaptation of the individual organism to his environment. To be adapted to leading solitary lives each must be self-directing, self-sustaining, and self-reproducing.

No animal organism, strictly speaking, is self-sufficient. It is questionable whether any animal species consists of individuals that have such capabilities. Or to put it in another way, it is doubtful if any animal organism has existed or could exist as an isolated unit. If we narrow the concept to mean species which

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\* By Professor Horatio Hacket Newman (see note at the head of Chapter XVI).

may continue or thrive after propagation independent of their own kind, the nearest approach is the parasite. This type of organism lives a more or less isolated life; and there are animal species, such as the carnivora, which are called "solitary" to distinguish them from others which depend on colonization for protection, food, etc. But in every case the parasites and the carnivora are dependent on other species. There are adaptations, however, which make for independence. Many plants (all the flowering species) as well as parasites and some of the more highly developed animals are male-female (hermaphrodite); therefore, the individuals are not concerned about a member of the opposite sex for reproduction of species. Others develop their own protective devices, such as the clam. Others develop capacity for solitary food gathering. With what has been said about individual efficiency we may pass to the cooperative aspect of "fitness" to live. It is this aspect in which we are chiefly concerned when considering adaptations that make for abundance.

**Adaptations Favoring Efficiency by Cooperation.** Too little thought is given the collective aspect of living. In this chapter we shall concern ourselves with ways in which individual organisms adapt themselves to other individual organisms and here interest centers in adaptations by means of which the functioning of the mechanism of one individual or species serves to increase the efficiency of another which the individual or group is dealing with. All cooperative arrangements are of this kind. That is, all cooperative arrangements are schemes of living which have proved to be mutually advantageous. If this is not the result, the cooperating could not long continue.

**Associations.** As has been said, some species have come to be more independent than others. Members of the cat family are frequently referred to as leading solitary lives, or as being solitary in their habits of getting a living. But as a matter of fact they are not independent. The mountain lion hunts alone, and alone faces its enemy. Other species live what are called social lives. The dog family hunts in packs; the bison grazes in herds and presents a solid front of horns to the wolf-pack or other foe. Broadly speaking, each living thing depends more or less on other living things—unless it be the lowest orders of protista or the

subcellular species. While there are many species which do not live social lives, their success depends on adaptations which definitely relate them to other species. The multicellular species could not live without the unicells; animals depend on plants; and plants are made more abundant and become more highly developed by animals. This is not the time or place to enlarge on the balance which has been established in the complex of living things as they have been evolved during the many geological ages. We are dealing with four classes of cooperation among species with which we are familiar.

**Temporary and Non-Formalized Associations.** In groups of animals otherwise isolated and self-sufficient, the demands of mating and reproduction cause aggregations of individuals of opposite sexes that may be seasonal only; but they are sometimes permanent. Migrational contingencies commonly bring about immense aggregations—as in many species of birds and not a few animals. In such temporary groupings there arises a flock or herd spirit which has in it more than a suggestion of societal tone. There appears to be an underlying feeling that there is safety in numbers and that it is well to stick together in emergencies. These loose associations due to a vague “instinct of the herd” may perhaps be excluded from our subsequent discussion as being more within the province of the psychologist or the sociologist.

**Mutual Aid.** There is a kind of non-formalized association called “mutual aid”—although the term is applied to include all cooperative arrangements. Kropotkin, the great Russian social scientist, has given to the world an outstanding treatise on the subject. And in this he enlarges on the mutual interdependence of different species. For the present we shall confine our attention to associations held together by much more tangible bonds.

**Types of Permanent Associations.** When classified in terms of bonds, permanent and formalized associations are of four different types: (1) *the unicell colony*—a form of association between members of the same unicell family in which individuals are held together by physical bonds; (2) *the commensal*—a type of association between animals of different species, in which each is physically free and the bond is instinctive; (3) *animal communi-*

*ties*—forms of associations between individuals of the same family or species held together by instinctive bonds; (4) *human communities*—forms of association in which both the bonds of union and the controls are a product of “culture.” This is distinguished by greater individual freedom—because while the basic psychic bonds are instinctive and operate automatically, the element of individual and group intelligence enters to condition instinctive reactions. Both the psychic and the physical mechanisms and environment are thereby adapted to conceptions of purpose. Human society in contradistinction has been characterized as “a complex of willed relations.”

### Colonization Among the Unicells

**Cooperation with Little or No Specialization.** Among the one-celled animals and plants (protista) there exists a pronounced tendency for the products of cell division to adhere and to form cell aggregates instead of separating after division to become independent individuals. In the simplest instances the colonial condition involves only four, eight or sixteen cells and is merely temporary. In such simple colonies there is usually no differentiation of cells for different functions. In slightly more advanced colonies, such as proterospongia, there is the beginning of division of labor, for, while the external cells are all alike and serve a nutritive, protective, and locomotor function, some of the internal cells become germ cells and subserve a reproductive function. Among larger colonies, such as volvox and colonial ciliates, the distinction between body cells and germ cells is more sharply defined and germ cells become differentiated into eggs (macrogametes) and sperms (microgametes). In colonies of one-celled organisms (protista) there is no division of labor among body cells. If such a step were taken, the arbitrary lines between subkingdoms would be transgressed and we would have to call such organisms multicellular animals or plants (metazoa and metaphyta). In a restricted sense the higher animals and plants may be looked upon as “cell-states” or colonies of one-celled organisms (protistan individuals) in which various individuals of the lower orders have given up their versatility and independence by merging their specialized identities into the larger individual

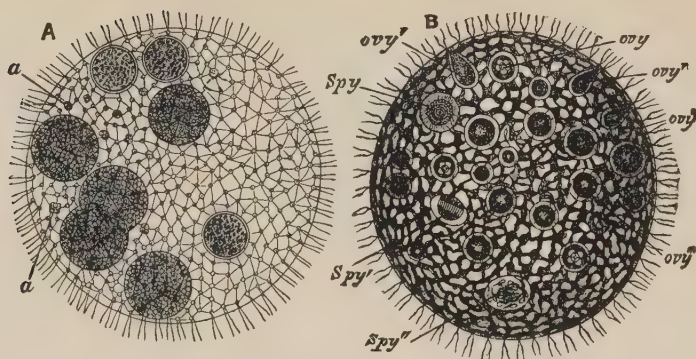


Figure 77. The Volvox. (From Weyssse.)

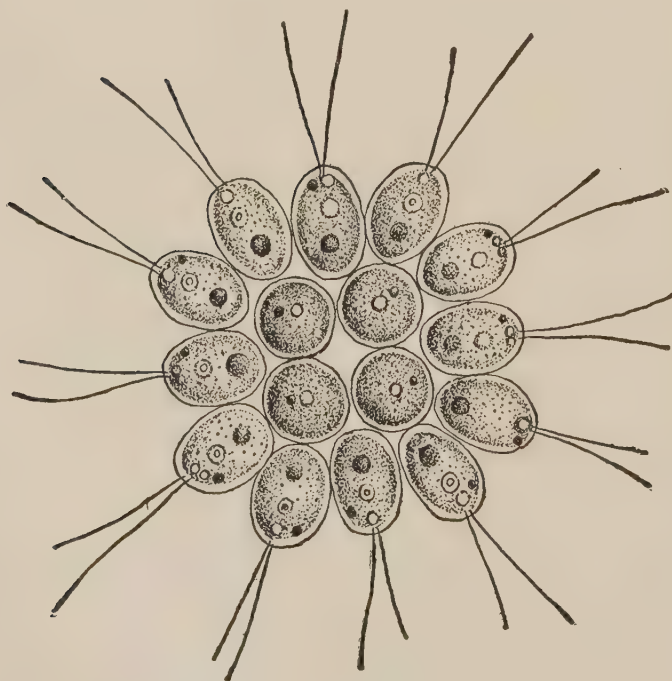


Figure 78. A Colony of Flagellata. (From Weyssse.)

of which they are members. Unless, however, there is some definite coordination between such units they do not constitute an organism in the true sense.

### Commensalism

**Cooperation Between Different Species.** It is impossible for a highly organized species of animal or plant to live alone. Every complex organism has commensals within its body or upon its surface or at least living within its shelter. More commonly than not, the relation between two commensals is that of host and parasite; and there are numerous benign or harmless parasites and some that are indispensable to the host. It is well nigh impossible to draw the line between those cases in which there is mutual aid between commensals and those in which the advantage is chiefly one-sided. But even in the latter case the relation must be favorable to continuity even of the less favored species.

A beautiful example of benign commensalism in termites has recently been described by Cleveland. These wood-devouring insects have as intestinal commensals certain species of unicellular animals (ciliates) that are able to digest cellulose (wood fiber) and render it available for assimilation by the termites. If the latter have no ciliates of the right sort in their intestines they are utterly unable to digest cellulose. Thus the ciliates are benefited by their protectors and in other ways in an advantageous environment, while they pay rental by helping in the nutrition of their hosts.

**Strange Cases of Commensalism.** A strange case of commensalism is that between various species of shark suckers (*Remoras*), curious fishes that attach themselves to the bodies of sharks and other large fishes by means of a sucking disk on top of the head. The *Remora* merely rides the shark, as a man would ride a horse, and leaves its steed only to make a sudden dash through the water to capture food. They are swift swimmers for short dashes and are able to capture small food fishes, then to overtake their steeds and continue their ride for weeks at a stretch. Mutuality is not evident in this case, for the shark is not benefited in any way unless he enjoys the *Remora* for company or as a pet.

Among the coral reefs of the South Seas there occurs a species of very large sea anemone that measures sometimes as much as two feet across the disk of the tentacles surrounding the mouth. The large mouth opens into an extensive cavity (the gastrovascular cavity) which is the equivalent of a stomach.



Figure 79. Commensalism. A Portuguese man-of-war (*Physalia*), with man-of-war fishes (*Nemeus Gronovii*), living in the shelter of the stinging feelers. (From Jordan and Kellogg.)

Within this cavity dwells a small fish, which, if removed, swims right back into its lodging. The little fish is of a brilliant vermilion color with three white cross bands, and is said to be quite conspicuous. The bright little fish is apparently liable to attack and escapes by darting into the mouth of the sea anemone. The pursuing enemy is said sometimes to blunder into the outspread tentacles of the polyp and to meet with innumerable sting cells which paralyze it and make it easy prey for the voracious owner of the tentacles.

#### Commensalism Among Ants.

Wheeler has described in most interesting fashion many instances of commensalism among ants. In certain cases one species lives almost wholly at the expense of another. Thus the little yellow thief-ant is a very frequent dweller in the galleries of the larger ants, where it subsists upon the live larvae and pupae of the host. The thief-ant is so tiny and inconspicuous that it apparently es-

capates the notice of the host. Another case among ants where the association between two species is an obviously one-sided one, is that between the larger red-brown ant (*Myrmica brevinodes*) and a smaller ant (*Leptothorax emersoni*). The latter lives in the nests of the former, building chambers with narrow passages communicating with the host galleries. When hungry, the small ant in-

vades the galleries of the host, climbs upon the back of a larger ant, and then proceeds to shampoo with its tongue the face and the back of the head of the host ant. Wheeler vividly describes the sequel as follows:

A *Myrmica* thus caressed "paused as if spellbound by this shampooing and occasionally folded its antennae as if in sensuous enjoyment. The *Leptothorax*, after licking the *Myrmica's* pate, moved its head round to the side and began to lick the cheeks, mandibles and labium of the *Myrmica*. Such ardent osculation was not bestowed in vain, for a minute drop of liquid—evidently some of the recently imbibed sugar-water—appeared on the *Myrmica's* lower lip and was promptly lapped up by the *Leptothorax*. The latter then dismounted, ran to another *Myrmica*, climbed on its back, and repeated the very same performance. Again it took toll and passed on to another *Myrmica*. On looking about in the nest I observed that nearly all the *Leptothorax* workers were similarly employed." It is Wheeler's belief that the *Leptothorax* obtain food only in this way, and that the only benefit, if such it may be called, that is derived by the *Myrmica* is the constant cleansing of head and face by their voluntary blandishers.

**The Brown Ant's "Cows."** The commensalism that exists between the brown ant (*Lasius brunneus*) and the corn root aphid (*Aphis maidisradica*) is a particularly good case of mutuality. According to Forbes, this aphid, in the autumn, commonly deposits its eggs in the ground of corn fields, often, by accident possibly, in the galleries of the brown ant. The eggs of the aphid hatch out the following spring before the corn is planted. The ants are extremely fond of the honey-dew secreted by corn root aphids. When the aphids hatch in the ant galleries, the ants carry them to the roots of grasses that serve as substitutes for the corn roots until the latter are ready for use. They are then transferred to the corn roots. It is thought that the ants even collect aphid eggs in the autumn and store them in their galleries. One must not attribute to the ants too much foresight in this case, for ants are always insatiable collectors of food for storage and doubtless the aphid eggs are gathered for food. That they hatch out into ant-cows before they are needed for food

saves their lives and serves to perpetuate the species. In all such cases there are many problems of a psychological character that have not been solved, but as instances of animal associates they are of great value. One cannot but marvel at the nicety of adaptive adjustment that exists among the numerous animals and plants of a given community. The lesson that must be drawn

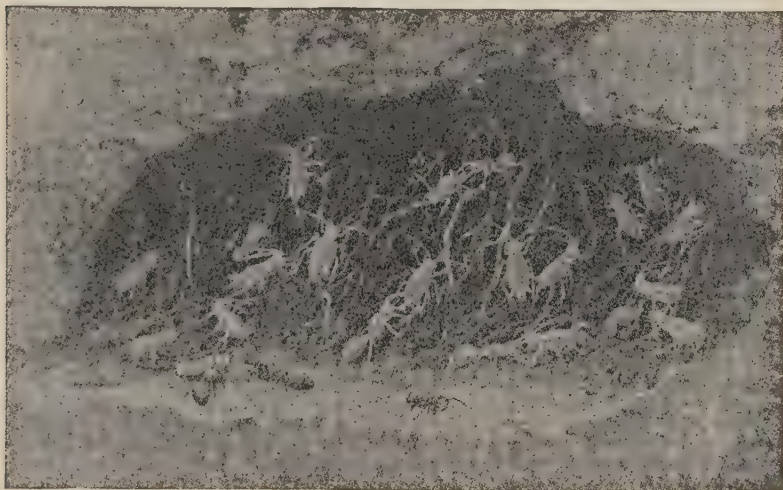


Figure 80. Ants Attending Aphids on the Roots of Grasses and Other Herbs. (From Wheeler.)

from such studies is that all nature is a tangled web of interdependencies and that no species can live alone.

### Communal Life Among Animals

**Cooperation Between Members of the Same Family or Species.** Some of the most successful species of animals owe their success chiefly to their social organizations. Outstanding examples of social animals are men and the bees, wasps, and ants. With man, societies are largely artificial and loosely organized, but none the less adaptive to a high degree. Among ants, a community is simply an enlarged family in which all the individuals are the offspring of the same mother and father. Other instances of communal life are the vast assemblages of sea-birds on certain oceanic islands which offer most suitable situations

for breeding. Such assemblages may be partly for mutual aid but seem to be largely effected through crowding in cramped quarters. Herds of Rocky Mountain sheep, villages of prairie dogs, beaver towns, and other assemblages are partly founded on kinship, but doubtless are also prompted by the instinct for uniting forces against a common enemy.

**Various Grades of Communities Among Insects.** Among bees we have examples of several steps leading from solitary life to a fairly advanced type of communal organization. The green carpenter bee (*Ceratina dupla*) is solitary. Each female bores out the pith from elder twigs and uses the hollow for making chambers for depositing her eggs. Each chamber is occupied by an egg with enough food to last the young till it arrives at adult life. The mother waits around till the young all emerge and then leads them off to learn the duties of adult bees. There is here the element of parental care which is the foundation of communal life, but the community is very short lived. A mining bee (*Andrena*) shows another step in the development of communal life. Several females build their homes in very close contact, forming villages of cottages, as it were. In another mining bee (*Halictus*) several females cooperate in building an apartment house, with one common entrance hall but with a separate apartment for each female, all opening into the common hall. The bumble bees are the most primitive of bees to form communities with real communal life. The occasional bumble bee one sees in the winter or early spring is always a fertilized queen, for all workers and males die in the autumn. When spring comes each queen finds for herself a deserted fieldmouse hole or some other suitable hole in the ground, gathers a mass of pollen which she rolls into a ball and deposits in the hole. On this food ball she lays her eggs. The eggs hatch out into young grubs (larvae of the bees) that feed upon the pollen, and after passing through the pupal state, issue as workers—winged bees smaller than the queens. They are females in sex though nearly always sterile. These workers gather more pollen and bring it to the nest where they make more pollen balls for the queen to lay further eggs upon and thus produce more workers. This is kept up until a considerable community is built up from the progeny of one

queen. Later in the summer, through the ability of the female to lay fertilized or unfertilized eggs, males and females are produced, the females coming from fertilized and the males from unfertilized eggs. By feeding some of the females a special diet they become sexually mature queens and mate with males. When winter comes all die off except the mated queens who have acquired a store of sperms ready to fertilize the eggs the following spring.

**Communal Life of Honey Bees.** Regular *honey bees* have a similar social organization and differ only in that the communities are larger and more nearly permanent, sometimes comprising as many as twenty or thirty thousand individuals. In a large community there may be, in addition to the one queen, several hundred males or drones, and many thousands of sterile female workers. The queen does all the egg laying and is the mother of the whole colony. The drones are mere royal consorts and have no useful function except to furnish a considerable choice from which the queen may choose her one mate when mating time comes, or to act as mates for any new queens that the community may produce. The workers, as their name implies, do all the work of the community, securing food, caring for young, house-cleaning, comb-building, and honey-making. They do not work alone or each on her own account, but all work for the common good. Individual welfare is completely submerged in communal welfare. The sterile females rule and regulate the life of the community not by imposing individual orders upon others but by each minding her own business and automatically passing from one necessary task to another until all are properly taken care of. There is nothing to indicate that individual bees have any conscious nationalistic aims or emotions, for their behavior is entirely inborn, stereotyped, instinctive.

**The Highly Developed Ant Community.** *Ants* exhibit various modifications of communal life, some being less elaborate than that described for bees and some considerably more complex. Among the more than two thousand known species of ants there are very many different kinds of homes and a great variety of feeding habits. They are all alike, however, in at least one respect; the sexually developed males and females are

winged while the sexually undeveloped female workers are wingless. Quite commonly these workers are differentiated into several castes, large workers, small workers, and soldiers. The usual home of ants is subterranean and consists of galleries and chambers. Some of the rooms are used as storerooms for food, others as nurseries for care of young, and still others as stables for "ant cattle," as aphids are sometimes called. In some of those species in which certain of the workers are specialized as "soldiers" these individuals do nothing but protect the community from raids of predacious insects, chiefly other species of ants. In other species the soldiers assume the rôle of raiders, armies of them attacking communities of other ants and, if victorious, looting and carrying back home with them the food stores of the vanquished. They even go so far in some instances as to enslave the conquered community in a peculiar way. They carry back to their nests the young, usually the pupae of their victims, and when the young hatch out they act as if they were at home, merely doing the work of the community without hesitation or complaint. The slave-making habit goes so far in some species that all of the true workers of the community are slaves and the entire population of the slave-makers, except queen and males, belongs to the soldier caste. These soldiers are so specialized for war and rapine alone that they are absolutely dependent upon the slaves for the gathering of food and the rearing of young. Indeed, it is claimed that the soldiers cannot even feed themselves, but must be fed by their slaves. Among the typical robber ants there are four kinds of individuals: winged males, winged females, small and large wingless soldiers. The small soldiers are believed to be infantry privates while the large soldiers are looked upon as officers. When on the march the ordinary privates are arranged in long, narrow columns while the officers go ahead or are scattered along on either side of the column and seem to act as scouts or directors of the line of march.

**Communities of Termites.** In *termites* (commonly called "white ants," but not ants at all) the communities may be made up of hundreds of thousands of individuals. They build great tower-like mounds fifteen feet or more in height. Their communal life resembles that of ants in many respects, but it differs in that

there are several more kinds of individuals in a community. Thus, there are sexually mature winged males and females, sexually mature wingless males and females, sterile male and female workers, and sterile soldiers of both sexes. The complex life of such communities would well repay more extensive study, but would require more pages than we can spare. They have a special interest here only to show the extent to which individual and group specialization may go in communities made up of individuals whose bonds are instinctive, and whose responses are automatic—and especially to show how successful they have been in adding to their members.

### The Beginnings of Human Society

**A Higher Type of Adaptation.** Human society, from the viewpoint of adaptation, is the highest type of association. In this relation we are not to do more than note some of the most broadly significant facts about it. Its two outstanding successes from the viewpoint of adaptation are to be found in the higher development of the nervous system, as a mechanism of conscious adjustment, by processes of habituation after birth; and the capacity developed for invention of means of achieving conscious objectives—the capacity for modifying and controlling environment both social and physical so as to vastly add to the abundance of human life. Human society (as a complex of willed relations) doubtless grew out of human communal life—living together in response to automatic instinctive responses. Whether the first community was a “sinless horde” or a blood-related group need not be discussed here; nor need we consider the evolution of that characteristic thing known as the human mind. As said before, our purpose is simply to note that among the devices evolved by which abundance of life is assured is this distinctive type of cooperation—a type distinguishable by having brought into it a different order of “ties which bind”; and that as a result, different mechanistic arrangements have eventuated “communities” of a new kind: communities in which there is a “moral order”; communities in which “institutions” are established but which are variable; communities in which specialized

groups come to form "associations" that in one aspect (political association) take form as business and other associations.

These may be thought of and discussed by other writers in this series as contributions of man to the solution of the problems of living.

**Summary.** However varied may be the organization of animal associations, they all subserve the important function of favoring the production of large numbers; and they make possible adaptations, both within the organism and in environment, favorable to maintenance of the increasing numbers produced. These cooperative arrangements, therefore, have a definite biological significance in that they tend to assure abundance of life. These general conclusions seem warranted—whether they are merely aggregations of individuals of the same kind physically bound (as in a "germ-culture" or other unicell colony), "commensals" belonging to different species, true "communities" such as of bees, wasps, ants, and termites, or "societies" in the human sense (in which mind enters as an habituating and determining agent). These general conclusions seem equally true whether individuals adapt themselves to living in associations that are simple or complex, whether the adaptations are instinctive as in the case of a community of ants, or are guided by reflective reasoning, as in the still more complex relations worked out by humankind.

## QUESTIONNAIRE WITH READING REFERENCES

### 1. How is "abundance" related to "continuity" of life?

- H. H. Newman, *Outlines of General Zoölogy* [N. Y.: Macmillan, 1925], Inhabitants of two square feet of soil, pp. 88-89; Ch. XXXIII, Web of Life, pp. 390-395.  
 F. O. Bower, *Plants and Man* [N. Y.: Macmillan, 1925], Ch. XXII, Plant population and conjoint life, pp. 257-267.  
 C. Darwin, *The Origin of Species* [N. Y.: Appleton, 1901], Ch. III, Struggle for existence, pp. 75-96.  
 A. R. Wallace, *Darwinism* [London: Macmillan, 1923], Ch. XII, Geographical distribution of organisms, pp. 338-374.  
 R. S. Lull, *Organic Evolution* [N. Y.: Macmillan, 1926], Prodigality of production, pp. 102-103.  
 D. S. Jordan and V. L. Kellogg, *Evolution and Animal Life* [N. Y.: Appleton, 1908], Ch. IV, Factors and mechanism of evolution, pp. 48-56.

### 2. What are the two most general types of solutions for assuring abundance of life? Discuss in terms of adaptations for solitary life and cooperation.

- J. M. Macfarlane, *The Causes and Course of Organic Evolution* [N. Y.: Macmillan,

1918], Ch. XXVII, Competitive system amongst the lower animals and man, pp. 751-767.

3. What is usually meant by "solitary life" and how are adaptations which add to the efficiency of the individual related to the general subject of evolution?  
Macfarlane, *op. cit.*, pp. 751-752.
4. What form of adaptation must be given first place in providing for the welfare of individual organisms?  
Macfarlane, *op. cit.*, pp. 751-752.
5. What is included in the general term "cooperation"?  
Jordan and Kellogg, *op. cit.*, Ch. XVIII, Mutual aid and communal life among animals, pp. 369-397.  
P. Kropotkin, *Mutual Aid* [N. Y.: McClure Phillips, 1902], whole book, 328 pp.
6. Thinking of the various main branches of living things as having been mutually aided, and of life as having become increasingly abundant because of the contributions of the several kinds each to the other—what may be thought of as the chief contributions of the unicells?
7. What has been the chief contribution of the multicells?
8. Among multicells what has been the chief contribution of plants?  
P. G. Stiles, *Human Physiology* [Philadelphia: Saunders, 1916], Ch. II, Plants and animals, pp. 25-36.  
P. G. Stiles, *Nutritional Physiology* [Philadelphia: Saunders, 1915, 2nd ed.], Ch. II, Energy relations of plants and animals, pp. 20-27.
9. Among multicells what has been the chief contributions of animals?
10. What is meant by "commensals" as distinguished from "associations"?  
Jordan and Kellogg, *op. cit.*, Ch. XVIII, Mutual aid and communal life among animals, pp. 369-397.
11. What is meant by "temporary and non-formalized associations"?  
E. D. Martin, *The Behavior of Crowds* [N. Y.: Harper, 1920], Ch. II, How crowds are formed, pp. 11-50.  
W. Trotter, *Instincts of the Herd in Peace and War* [London: Fisher Unwin, 1916], General characteristics of the gregarious animal, pp. 29-41.  
G. LeBon, *The Crowd* [N. Y.: Macmillan], Book III, Ch. I, Classification of crowds, pp. 177-189.
12. What is meant by permanent associations? Give names of four general classes.  
Lull, *op. cit.*, Ch. XVI, Animal association, communalism, pp. 248-261.
13. What is meant by a "commensal"?
14. What is meant by a colony?
15. What is meant by a swarm or herd?
16. What is meant by an organized community?
17. What is a unicell colony? Give illustrations of colonization among unicells.
18. Give illustrations of colonization among unicells without modification of the structure of individual members.

A. W. Weyssse, *A Synoptic Text-book of Zoölogy* [N. Y.: Macmillan, 1904], Ch. III, Type protozoa, pp. 19-50.  
 Newman, *op. cit.*, Ch. XIII, Protozoa and metazoa, pp. 137-143.

19. Give illustrations of colonization among unicells in which individuals are structurally and functionally specialized or differentiated.

Weyssse, see reference to question above.

Newman, see reference to question above.

20. Distinguish "commensalism" as a form of cooperation from "colonization" and "community."

Jordan and Kellogg, *op. cit.*, p. 370 (Commensalism); p. 373 (Symbiosis).

21. How is a "community" distinguished from "commensalism"—what are the advantages of communal life?

Jordan and Kellogg, *op. cit.*, pp. 395-397.

Lull, *op. cit.*, Ch. XVI, Animal associations, communalism, pp. 248-261.

22. What is characteristic of an animal or insect community as distinguished from a human community?

Lull, *op. cit.*, Mankind, p. 261.

23. Give illustration of commensalism which is of advantage to, (a) termites, (b) sharks, (c) sea anemones, (d) ants, (e) *Myrmica*.

Jordan and Kellogg, *op. cit.*, Ch. XVIII, Mutual aid and communal life among animals, pp. 369-397.

Newman, *op. cit.*, Ch. XXI, Ants and social organization, pp. 240-245.

24. Give illustrations of communities of insects.

Lull, *op. cit.*, pp. 251-261.

M. Maeterlinck, *The Life of the Bee* [N. Y.: Dodd Mead, 1917], whole book, 422 pp.

Newman, see reference to question above.

25. Give illustrations of communities of quadrupeds.

26. Discuss human communities as a higher type of adaptation—with special reference to the development of intelligence, sentiments and will.

Kropotkin, *op. cit.*, whole book, 328 pp.

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 H. H. Newman, *Evolution, Genetics, and Eugenics* [Univ. of Chicago Press, rev. ed., 1925], especially Chs. XVI, XVII.  
 R. S. Lull, *Organic Evolution* [N. Y.: Macmillan, 1926], Chs. XVI-XXIV, inclusive.

## CHAPTER XX

### NATURE'S SPECIALIZED DEVICES OF ADAPTATION

#### HEREDITY AND VARIATION \*

**Determinants of Success of Species.** The permanent success of any species is determined by two kinds of characteristics inherent in the type as such: (1) as a type it must have the ability to *conserve* those structural and functional particularities that have proved advantageous to ancestors and which still have a survival value in the circumstances then present, and (2) it must have the ability to *modify* its adaptive features so that, as an organism it will be suited to changes in environment—for continuity in the life stream is conditioned by the necessity that each species shall adapt itself to the permutations of a changing world. It is only through the adaptive powers of its mechanism at any given time, and its ability to replace its obsolescent members, that the type can avail itself of the varying opportunities present to exploit nature. Given these two abilities, the species survives. The conserving process is called *heredity*. The modifying process is called *variation*.

**Mechanisms of Conservation and Progressive Adaptation.** Without heredity there could be no organic stability. Growth would be haphazard and there could be no progressive adaptation or development. Our conception of species as more or less permanently fixed types—and notice that we say “more or less”—is due to heredity. The older notion of reproduction has been gradually set aside by the results of scientific research. We now know that there is a very definite mechanistic arrangement which accounts for the persistence of species. On these mechanisms depend both heredity and variation. What these mechanisms are is set forth in the pages that follow. It is also to be

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\* By Professor Horatio Hackett Newman (see note at the head of Chapter XVI).

noted (a fact later discussed at length) that the mechanism of variation is also hereditary.

### Mechanisms of Heredity

**Adaptations in the Interest of Conservation.** The mechanism on which every organism depends for the conservation of structural and functional particularities that have proved advantageous to ancestors, is not one that replaces the progenitor with an exact duplicate in structure, as in the case of a chemical compound. There is a very strong tendency for any given kind of organism to reproduce offspring like itself. But there is never an exact duplication of the parent in the offspring. Heredity does not mean slavish multiplication of stereotyped replicas, generation after generation; it does mean an adherence to a more or less rigid standard of form or function with numerous minor departures in almost every part of the body of offspring from those seen in the parent body. Heredity, therefore, has been characterized as a tendency—the tendency to retain old characters; but the corresponding tendency to introduce new characters is always present.

**The Heredity Machine.** As was brought out in Chapter XVIII, heredity is fundamentally a matter of cell division. The “species cell” or germ cell (especially the egg) of any type has not only a definite organization as have other cells; the germ cell has a nucleus (containing chromosomes) and surrounding organic matter (a cytosome) with its characteristic polarity, symmetry, and an orderly arrangement of its peculiar organ-forming substances. But in the germ cell the nucleus has a characteristic set of chromosomes—definite and fixed in number, size, and shape for each species. A fact to be remembered about the chromosomes of a germ cell is that each kind of chromosome in the nucleus is found in duplicate. In other words, there are two of each kind of chromosome—except in gametes, about which we shall speak later (page 346). The distinguishing character of each kind of chromosome is traceable in its constituent parts. Each kind of chromosome in the nucleus consists of a series of little packets

of protein substances that are not only specific for the type in question but different from each other.

**Genes—The Bearers of Individual Characteristics.** Thus, each chromosome is like a train of freight cars in which each car carries a different cargo. These packets are called *genes*. And it is definitely known that each *gene* has a characteristic effect in

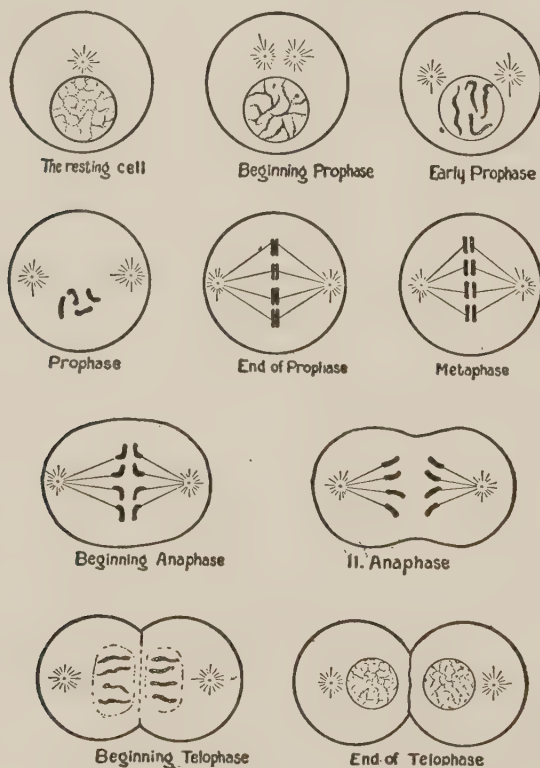


Figure 81. Diagram Illustrating Mitosis. (From Walter, after Boveri.)

determining the peculiarities of the individual that develops from the germ cell which it serves as a determiner. If the packets be changed, the end result will be altered—either markedly or slightly, as the change and conditions may determine. In brief, we may say then that each germ cell consists of a set of differing kinds of chromosomes, each kind existing in duplicate and each

of the duplicates having a very precious cargo of hereditary packets (genes) all of which are necessary to the continuation of a particular type of organism. Another fact to be remembered is that in each germ cell there must be some very sure and certain *method* of passing on this complex heritage to future generations. This method is described below.

**The Mitotic, or Cell-Dividing, Mechanism.** Growth in the germ (as in all other cells) is the result of cell-division whereby two cells come to be where one was before. The process is called "*mitosis*." The mitotic mechanism is in a very real sense the heredity machine. This mechanism of heredity is present when-

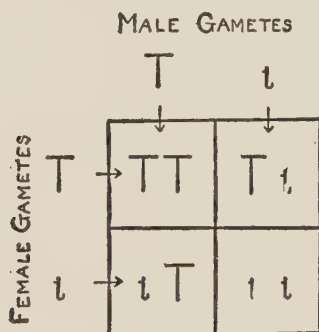


Figure 82. Formation of Zygotes. (From Walter.)

ever cells divide and helps to maintain the general characteristics of the type, such as polarity and symmetry. It also handles the chromosomes (chains of packets of genes) in such an exact and meticulous way that two cells are produced from one; and the two (daughter cells) are essentially identical with the one (mother cell) from which they came. Under the microscope, this process may be followed in greater detail from the dividing of the nucleus, to the dividing of each of the chromosomes within the nucleus. Each chromosome is split lengthwise into equivalent half-chromosomes; and when each chromosome is split, each of the halves contains half of each packet; that is, a third detail in the mitotic process is found in the splitting of the genes. Thus, the whole cell mechanism is so divided that each part becomes two half parts and even the hereditary packets contained in each chro-

mosome are split. Then, after the splitting is completed each half-chromosome by a simple process of assimilation and growth regains the full typical size. By this means each gene present in the germ (mother) cell is transmitted to the daughter cells, and by a long succession of such divisions a multicellular body is produced, each cell of which has the same chromatin elements as had the original fertilized egg (*zygote*).

**The Variation Mechanism.** In the process of cell division variation as well as heredity is also provided for. Some of the cells produced by cell division will pass on as germ cells to the next generation; and if it were not for the intervention of a variation mechanism, as an interlude between two generations, there might be a perfect repetition of the parental peculiarities in each of the offspring. This variation mechanism is called *meiosis*, and will be explained after we have considered some of the modes of laws of heredity characteristic of both animals and plants, and, of course, equally characteristic of man (see page 346).

**Mendel's Laws of Heredity.** Gregor Mendel, an Austrian monk of the nineteenth century, discovered the most significant facts about heredity through his studies of cross breeding in peas. He noted that the several varieties of peas differed from each other sharply in one or more so-called *unit characters*. Thus one variety might have round seeds, another wrinkled seeds; one variety might be of the tall vine type, another of the short bush type; one variety might have colored flowers, another white.

**Germinal Determiners.** These contrasting characters, or their germinal determiners, were known as *allelomorphs*. Thus, tall is the allelomorph of short, round of wrinkled, colored flower of white flower. Mendel discovered that when he crossed a tall plant with a short plant, the offspring of the first generation were all tall. Similarly, a cross between a round-seeded variety and a wrinkled-seeded variety gave all round-seeded plants. Many other allelomorphs showed the same result, namely, one or another character of an allelomorphic pair appeared in the hybrid (crossed) offspring to the exclusion of its alternative. The

character that appears is known as *dominant*, while the character that fails to appear is called *recessive*.

**Hybrids and Pure Breeds.** Now, when two of the first generation hybrid are bred together, their offspring give us a surprise, for, not only does the dominant character appear in its pristine form, but the recessive character reappears in some of the offspring although it has been lost to view for a whole

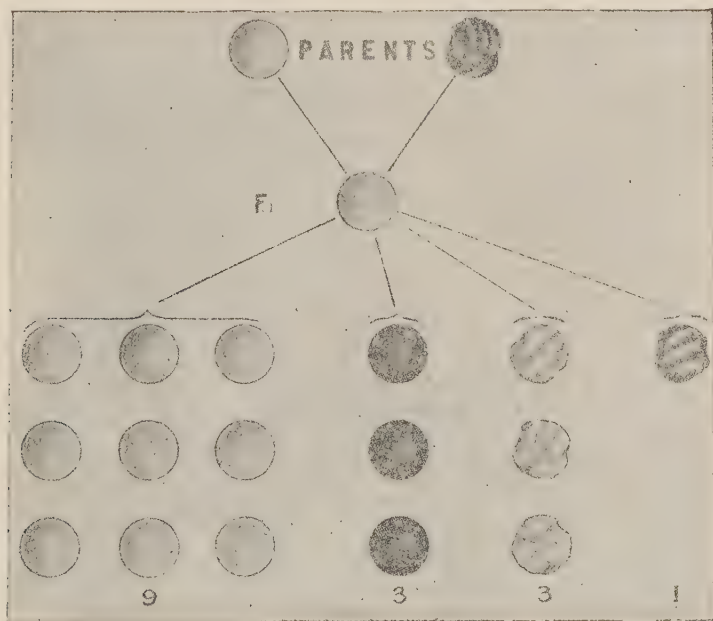


Figure 83. Mendel's Law. The crossing of yellow, smooth, and green, wrinkled garden peas. (From Calkins.)

generation. If large numbers of offspring are produced, there will appear a ratio of three dominants to one recessive. Thus, from intercrossing the first hybrids from tall and short parents, we will get in the next generation three tall to one short (or 3,000 tall to 1,000 shorts, if 4,000 plants are produced). Now what is the mechanism responsible for turning out this constant and exact ratio?

**The Pairing Process.** In order to answer this question we have to return to the chromosomes. Recall that there are in the

nucleus of each germ cell of any pure breeding type two of each characteristic kind of chromosome. In the tall variety of pea there are in the germ cell nuclei two chromosomes, each of which carries a gene for tallness. In the short variety, similarly, there are two chromosomes, each carrying a gene for shortness. As an interlude to starting a new generation there is a very significant preparatory step. If an egg cell with a double set of determiners in a double set of chromosomes divided after fertilization, a fertilized egg cell (zygote) would result with four of each of these hereditary packages, and each successive generation would double their number. To obviate this unnecessary and essentially impracticable contingency, there is a very neat scheme called the reduction division. This is one of the steps in the processes of the variable mechanism described above (meiosis). Just before the germ cells are fully ripe, and before fertilization, chromosomes choose partners and remain for some time paired.

**The Law Governing Choice of Partners—A Second Dividing Process.** Only equivalent chromosomes pair, and it is of utmost importance that this rule be not broken. In the experiment above referred to the germ cells of tall peas have two chromosomes carrying tallness; those of short peas have two carrying shortness. Now, the two tall chromosomes of the parent pair; and so do the two shorts of the other parent. Then a unique event takes place in each parent. Each germ cell now divides in such a way that one chromosome (not a half-chromosome this time, as in the mitotic process) of each pair goes to one daughter cell and the other to the other daughter cell.

**The Daughter Cells' Dowry.** Such daughter cells with the single set of chromosomes are known as *gametes*—instead of a double set as in the germ cell (page 342). A gamete can have either one of opposed or allelomorphic genes but never both. Now, each gamete of tall will have one gene for tall; while each gamete for short will have one gene for short. In fertilization, when egg and sperm (female and male gametes) unite, a zygote will be produced with two sets of chromosomes again, and there will be a gene for tall and a gene for short in the same zygote.

These zygotes will produce only tall plants because tall is dominant; but when the germ cells of the first hybrid generation undergo meiosis, each will have half of its gametes "tall" and half "short." A chance union of the two kinds of gametes to

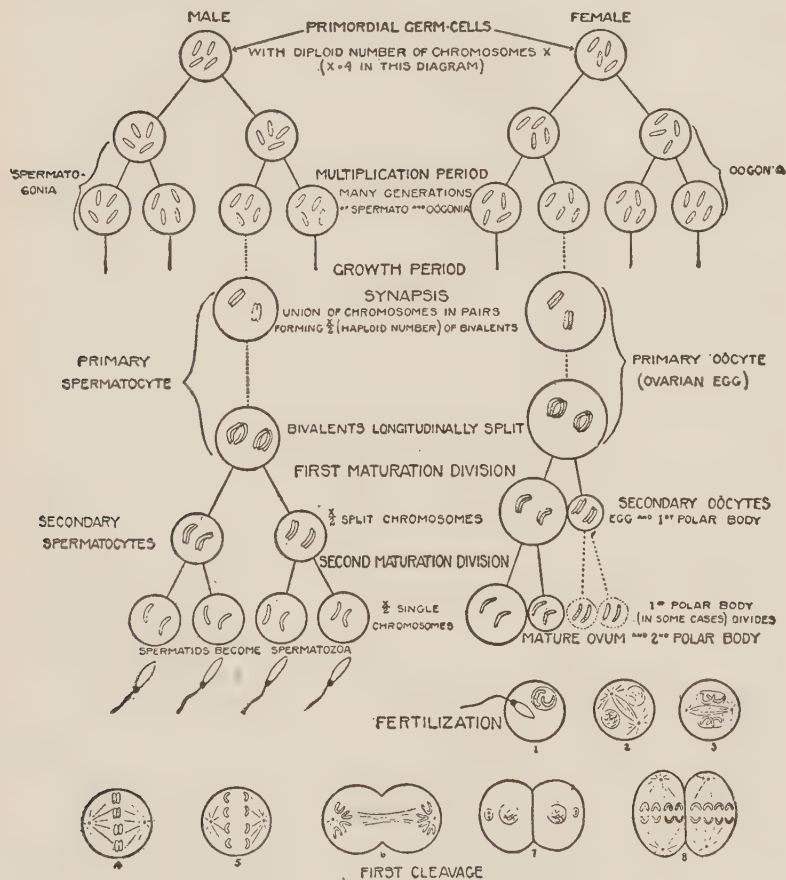


Figure 84. Maturation and Fertilization. (From Calkins.)

produce the second hybrid generation will admit of the formation of one "double-tall," one "double-short" and two "tall-shorts" out of every four chances. The "double-talls" and "tall-shorts" will look alike because tallness is dominant, and thus we will have the three dominants to one recessive, the regular Mendelian ratio

that applies to such cases the world over, whether in plants, lower animals, or man.

We have now presented the essentials about the laws of heredity and have described the machine which makes the regularities we call laws. It remains to show how this machine also brings about variation.

### Mechanisms of Progressive Variation

**The Creative Factor in Organisms.** In each germ cell the hereditary or conserving mechanism is in continuous operation; and within it also in continuous operation is another mechanism with a corresponding tendency to vary the type of structure—to create, we may say, something new. This tendency may be thought of as inherent in the same mechanism—which accounts for the fact that variation is always taking place in organs and organisms that are true to type. We may think of these (*reproduction* of parts true to type and *variation*) as two tendencies ever present in the mechanisms. They assert themselves in the development of species. They assert themselves in the development of each embryo or bud or reproduction part. They assert themselves throughout the life of each individual. For this reason Herick calls the development of each embryo a creation. And for like reason the psychologist conceives of each mind as a creation. That each species has a characteristic heredity mechanism is a commonly accepted fact. By way of contradistinction, however, every germ cell (every bud or slip when reproduction is thus carried on) may be conceived as having in it what we may fittingly call a variation mechanism.

**The Mechanism Which Operates to Produce Change in Types.** It happens that each pair of chromosomes in the germinal cell behaves in the operation of the variation mechanism (in meiosis) as though entirely independent of, and uninfluenced by the others. Working together, they may with much truth, be thought of as creative agents—as producing new combinations. If we think of three pairs of chromosomes as carrying the three pairs of allelomorphs already mentioned—"tall" versus "short," "round" versus "wrinkled," "colored flowers" versus "white

flowers," we can easily see that if each pair may turn in such a way as to cause its dominant gene to go to one daughter cell or the other quite irrespective of what happens in the other two pairs, we may have various combinations of dominants and recessives in the gametes.

♂→ ♀ ↓	TRC ↓	TRc ↓	TrC ↓	Trc ↓	tRC ↓	tRc ↓	trC ↓	trc ↓
TRC→	TRC TRC	TRc TRC	TrC TRC	Trc TRC	tRC TRC	tRc TRC	trC TRC	trc TRC
TRc→	TRC TRc	TRc TRc	TrC TRc	Trc TRc	tRC TRc	tRc TRc	trC TRc	trc TRc
TrC→	TRC TrC	TRc TrC	TrC TrC	Trc TrC	tRC TrC	tRc TrC	trC TrC	trc TrC
Trc→	TRC Trc	TRc Trc	TrC Trc	Trc Trc	tRC Trc	tRc Trc	trC Trc	trc Trc
tRC→	TRC tRC	TRc tRC	TrC tRC	Trc tRC	tRC tRC	tRc tRC	trC tRC	trc tRC
tRc→	TRC tRc	TRc tRc	TrC tRc	Trc tRc	tRC tRc	tRc tRc	trC tRc	trc tRc
trC→	TRC trC	TRc trC	TrC trC	Trc trC	tRC trC	tRc trC	trC trC	trc trC
trc→	TRC trc	TRc trc	TrC trc	Trc trc	tRC trc	tRc trc	trC trc	trc trc

Figure 85. Variation by Combinations in the Zygotes

**Variation by Combinations in the Zygotes.** Let us for brevity call tall *T*; short *t*; round *R*, wrinkled *r*; colored *C*, and white *c*. We then could get gametes of eight kinds in equal numbers, as follows: *TRC*, *TRc*, *TrC*, *Trc*, *tRC*, *tRc*, *trC*, *trc*. There would be the same assortment of female gametes and of male gametes. These would unite at random, and 64 combina-

tions would result if each combination occurred often. Thus we see how varied the offspring might be even when only three allelomorphs are concerned. Each additional difference doubles the number of combinations, so that when we consider man with 24 pairs of chromosomes, or some other animals with even twice that number, we can easily understand how millions of different combinations of individual differences may arise, and we cease to wonder that no two human beings are alike (except duplicate twins that come from a single zygote and hence have identical heredity).

Because of the fact that meiosis has the power to produce so vast a variety of combinations it may well be called the variation machine, just as we called mitosis the heredity machine.

**Somatic Modifications.** It is a commonplace fact that changes can be produced in organs by exercising them normally, excessively, or insufficiently; that performance can be altered by practice or the lack of it; that brain, eye, hand, intestines can be trained to act in different ways; that the body responds in different ways, both structurally and functionally to changes in food, water, light, temperature, or other environmental agents. As a rule, such changes are adaptive, helping the organism in its effort at self-maintenance. Since each individual has to acquire these useful adaptive modifications through its own individual effort, such changes are obviously not inherited. What is inherited is merely a capacity for adaptive response.

**Acquired Characters.** Common observation agrees with scientific opinion based upon experiment in concluding that acquired characters, i.e., characters attained through effort on the part of the parent, are not transmitted to offspring, so that the latter cannot secure these modifications without making an equivalent effort. There are biologists today who hold that some sorts of somatic modifications are inheritable, but the vast majority of biologists hold a contrary opinion. We may then say, with the majority, that there is no evidence at present that acquired characters (in the technical sense) are inherited. How, then, can a race progress or undergo evolutionary change, if parents' changes cannot be passed on to offspring? This is a natural and common

question and can be answered in a word: by means of germinal changes—mutations.

**Mutations—Germinal Alternations.** One of the outstanding discoveries of the last few decades is that new types of organisms are not infrequently seen to arise from old, and they arise quite suddenly in a single generation. The changes may be of a large and striking sort so that the new type appears at once to be almost a new species, or the change may be slight but clear-cut so that merely a variety is originated. Such new types, with a very few exceptions, breed true—and if isolated, would remain permanent new elementary species or varieties. If this is all true, how ridiculous is the statement of certain people that man has never observed the origin of a new species!

**Mutations—Not to be Considered “Sports” or “Freaks.”** Among the scores of species of animals and plants that have been used for the study of mutations, extremely few, if any, have disappointed the investigator. Mutations are relatively common—not the sort of thing that can be classed as “sports” or “freaks of nature.” In one species of fly (*Drosophila melanogaster*) that has been studied intensively for a score of years by a considerable number of geneticists, over two hundred different mutations have been observed and many of these have occurred several or many times in unrelated stocks. The bodily changes resulting from the germinal alteration (mutation) may affect the organism in many ways, i.e., eyes, wings, body, legs, bristles, colors and patterns, viability, fecundity, resistance, longevity, etc. The character of changes most easily observed and studied are external structural changes, though there is no reason to believe that these are any more frequent than internal structural changes or purely functional changes. An example of a large and striking mutation is one that involves the nearly complete loss of wings, for a wingless fly is almost a paradox—as much so as a wingless bird. An example of a small mutation is one that is evidenced chiefly in a very slight change in the color of the eye, as from red to vermilion. Some changes are so slight that only one sensitized by long study of the species could detect them.

**The Physical Basis of Mutations.** The answer to this question cannot adequately be given in the space allotted to this chapter. While no claim is made by the modern geneticist that an ultimate answer is possible, he has been able, by a most ingenious and far-reaching analysis of genetic data, to prove that a given

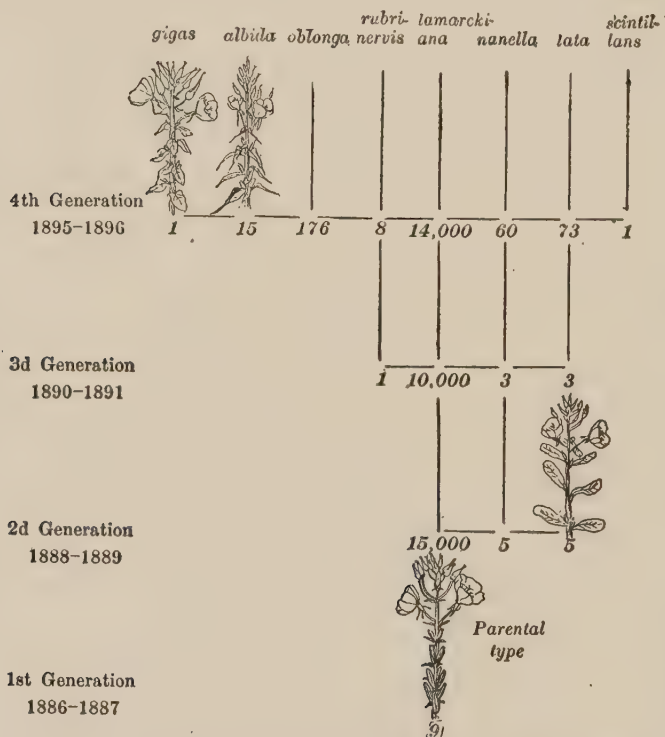


Figure 86. Chromosomal Aberration—Lamarck's Evening Primrose. (From Gruenberg.)

mutation is nearly always due to a chemical change in a single packet of chromatin, forming a definite part of a single chromosome. By carefully designed experiment it is possible to plot out the relative positions of all genes that have mutated, and chromosome maps of *Drosophila* have been made showing over two hundred loci of genes. Proof of the correctness of the maps and of the general hypothesis of a linear arrangement of genes on the chromosomes has come as the result of one of the most bril-

liant series of scientific advances of modern times, rivaling those in physics which have resulted in the present conception of atomic structure.

**Chromosomal Aberrations.** Mutations of another sort have been observed commonly in plants and occasionally in animals. Instead of a local change in a single chromosome being concerned, these changes involve the doubling of the whole set of chromosomes or the addition of one or more whole chromosomes to the set. The exact mechanisms involved in these chromosomal aberrations, as they are called, are not fully understood; but the results both in the bodies of the mutants and in the chromosomal complex are readily observed and are closely correlated. Whenever a chromosomal change occurs its inevitable consequence is a changed bodily equilibrium expressed in many altered characters. The classic instance of mutations resulting from chromosomal aberrations is that described first by De Vries for Lamarck's Evening Primrose (*Oenothera lamarckiana*). In this plant a score or more new elementary species (mutants) appeared suddenly and repeated themselves in a considerable number of individuals each season for many years. Nearly all bred true to type and were clearly recognizable as distinct new forms.

### Selection the Guiding Factor

**Natural Selection of Mutations.** Among gene mutations it may be said that nearly all changes were changes for the worse—at least under the prevailing conditions of life. Possibly under changed conditions of life some of the mutants would be better off than the normals. Very many of the changes were so detrimental that the changed individuals either died early or were sickly forms that would not survive in nature. Some changes, also, were too slight in themselves to be of adaptive value. It is doubtful whether in nature many of the mutant types would survive. This survival of the best mutants only would serve as a means for improving the organism along adaptive lines. Thus natural selection could play an important part in evolutionary advance in acting as an arbiter among the numerous mutations,

preserving only the rare few that possess adaptive value and eliminating those that are detrimental.

**Artificial Selection.** Man has usurped nature's prerogative in his handling of domesticated animals and plants. He selects the ones to survive, not on the basis of what would be best for the organism itself, but for what he can get out of that organism. For example, man wants fat from the hog for lard. He selects for fatness and goes so far with it that he breeds an obese race of hogs that are not nearly so good, from the hog's standpoint, as would be a good old razor-back.

**Improving the Human Breed.** The question arises as to whether man could control his own evolution by the artificial selection of types for particular purposes. Would it be advisable to give man the opportunity of doing for his own kind what he has done for the lower animals and plants? This is a difficult question to answer. Undoubtedly man could vastly improve the average status of human populations by eliminating some of the obviously weaker and less capable stocks; but it is not clear as to just what ideal types he should aim to produce. Even today natural selection may be working with a surer hand to advance the fitness of man than we at present know.

**The Problem of Acquired Characteristics.** In this chapter we have discussed the three primary factors of organic evolution; heredity, the conserving factor; variation, the creative factor; and selection, the guiding factor making for fitness or adaptation. Heredity and variation are different aspects of the operation of the equipment with which the individual is endowed by nature. The acquired characteristics are developed by reacting to stimuli received after birth. The special equipment of adjustment by reaction to stimuli is in the nervous system, which is the subject of the chapter that follows.

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## CHAPTER XXI

### NATURE'S SPECIALIZED DEVICES OF ADAPTATION

#### Instinct and Intelligence\*

**The Nervous System a Specialized Organ of Adaptation.** The preceding chapter dealt with two principles—heredity and variation. In the discussion attention was called to the tendency of organisms to follow type and the tendency toward change, two tendencies which are inherent in all organisms. The principles of heredity and variation determine the functions of the mechanism of reproduction. We must now deal with another principle, which may be called the individual selective principle—the disposition of the individual to choose between alternatives presented to sense, when making adaptation to the immediate environment. The more highly developed the mechanism of a species (for performing this function of choice), the wider is its range of possible adaptation. Plants and unicells employ the less delicate and often slowly responding mechanism of the tropisms, while the more complex animals make choices by means of a definite nervous system, which is progressively more highly specialized from the lower to the higher vertebrates, culminating in the primates. With a highly developed selective mechanism, not only does each individual react to external stimuli in ways characteristic of the species, but by so reacting each individual acquires characteristics peculiar to itself. The structural basis of this function of individual adaptation is a product of evolution. C. Judson Herrick, the neurologist, makes much of this faculty of choice. He calls it the creative principle.

The responses characteristic of the species are to be accounted for by heredity. They are the inborn tendencies to act or react

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\* Original manuscript prepared by Howard M. Parshley, Professor of Zoölogy, Smith College. A.B., 1909, A.M., 1910, Sc.D., 1917 (Harvard). Author: *Science and Good Behavior*, 1928; books and articles on the Hemiptera; Managing Editor, General Catalogue of the Hemiptera.

to stimuli in typical ways—tendencies which, with characteristic mechanisms, are handed on from generation to generation. These typical ways or behavior patterns are sometimes said to be the product of the biological experience of the race, in one sense or another. Tendencies or dispositions developed as a result of individual experience are in contradistinction called habits and *acquired* characteristics. Whether undertaken from the point of view of inherited or acquired behavior patterns, scientific study of the evolution of the nervous system of a species must be based on the frank recognition of the fact that the environment is the complement of the organism. The nervous system as a mechanism is an evolutionary product of reactions of the species to the environment in which it has lived. Both instinct and intelligence are thus evolved as functions of the specialized mechanism of adaptation. They are the contributions of nature to the solution of life's problems before the advent of man.

**Environment the Complement of Organism.** The characteristics of a full grown organism are developed by a process which begins with the formation of the egg (in which the principles of heredity and variation operate) and acts continuously throughout life. By the "individual," we mean here the organism with all its mechanisms and tendencies, as it is gradually modified by experience. The hereditary determinants are discussed at length in the preceding chapter. The changes which are attributable to individual experience are products of the continuous reconstruction of the protoplasmic mechanisms in which vital energy is developed and through which it manifests itself. This interaction, indeed, is so intimate that we can never distinguish with certainty and completeness between the organism and its environment—useful as the differentiation often is when dealing with particular problems of adjustment. To avoid oversimplification in this connection, we should always bear in mind that beyond the obvious relation of the ever-changing individual to an ever-changing environment there is the more obscure though vital fact of internal dependence of its functioning parts; every structural part of an organism has as an essential aspect of its environment, the rest of the body.

**The Complement of Specialized Organs—Need for Correlation and Adaptation.** A certain degree of internal correlation (integration) is requisite in order that the individual organism may develop at all; but more than this is needed if the organism is to succeed in the struggle for existence and leave offspring. It must exhibit a nice adjustment to the surroundings which fate (or circumstances over which it has no control) has thrown around it. There is need for adaptation of its own inherited mechanism, as well as for environmental change. In a word, every organism receives stimuli from its environment. In some fashion it must interpret the meaning of these stimuli in relation to its own interests if it is to respond with appropriate movements. Otherwise it must meet an early death. The behavior of any animal is the sum total of such activity. What its activities shall be is determined by its inherited equipment as modified by experience—its second nature. And behavior is in large part regulated by the specialized organ of adaptation—the nervous system. The manner in which this reacts to stimuli and thereby controls behavior is the subject of this chapter.

**Specialized Equipment Which Controls Behavior.** In all but the lowest types a specialized anatomical system of nerves is present; but even in the lowest types the same necessities for adaptation and control exist, and the same basic functions are carried on as in the highest types—although specialized nervous tissue may be completely lacking. Sensitivity is an inherent quality of protoplasm and without it protoplasm could not be a material adapted for use in vital mechanism. It is to these lower forms that we must first give our attention, if we are to understand the biologic conditions that underlie instinct and intelligence.

## **The Mechanism of Correlation and Adaptation**

**Inherent Functions of Protoplasm.** The living substance of the simplest known organisms has undergone a long evolution and thus it is not so simple as it seems; at any rate, a one-celled animal, without organs or tissues, can and does carry on each and all of the primary functions of life—protection, expropriation, digestion, circulation, metabolism, elimination of waste, etc.

There are three functions which are of special interest in the present connection, viz., *sensitivity*, *conductivity*, and *contractility*. An amœba gently touched on one side responds with movement on the other. Here we have reception of the stimulus, transmission of the impulse, and appropriate movement—in brief, the



Figure 87. Behavior of Vorticella when Disturbed. (From Gruenberg.)



Figure 88. Behavior of Stentor when Stimulated by Carmine Particles. (From Pillsbury, after Jennings.)

essentials of adaptive behavior. But all this goes on within a single cell, a mass of continuous, relatively undifferentiated protoplasm; and, as might be expected, none of the three functions are highly efficient, adequate though they are for the minute sphere in which they work.

**The Physiological Gradients.** Recent experimental studies of the most exact and convincing nature have demonstrated the existence in organisms (both primitive and specialized) of the

*physiological gradients.* By this is meant that in different parts of the body of an organism there is a different rate of change going on in cell and molecular structure in the process by which energy is released. There are lines of diminishing or increasing metabolic activity. These gradients (or differentials in the rate of metabolism) appear to be of a very fundamental character—



Figure 89. Behavior of Paramecium. When the animal runs into an obstacle (O), whether physical or chemical, it immediately reverses its movements, backs off a little, turns to one side, and starts along a new path. (From Gruenberg.)

since they are to be observed in all living bodies and since they profoundly affect ontogeny, behavior, and undoubtedly, the evolutionary process. This general conclusion may be made concrete as follows: In a higher protozoan or one-celled organism (for example, a paramecium), one end normally goes first in locomotion. This end has a high rate of physico-chemical change (metabolism). And the part in which the energy-producing change is most rapid is especially sensitive; the end of the organism which meets environment first and is most sensitive

produces receptive structures which serve as aids to adjustment. It is the plus end of the gradient series; and these conditions determine one pole of the chief axis of the body exemplified in the nervous system. Along this axis metabolic activity becomes gradually less and less until the other end is reached, where there is often a second intensification of a minor nature.

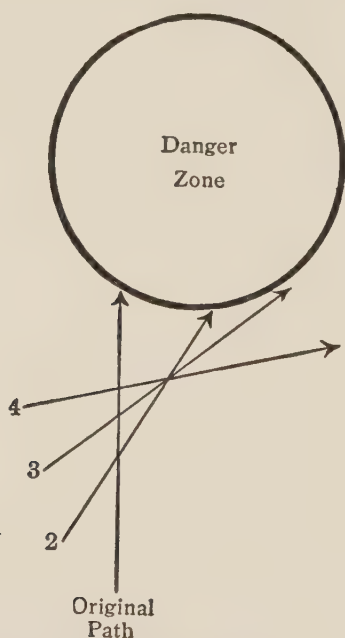


Figure 90. Trial and Error in the Lowest Animals. On coming into a region unfavorable to its existence, the stimulus causes a reversal of its movements, with a change of direction. On moving forward in a new path, 2, it may again meet the same obstacle. The same reaction is repeated. After a number of trials the animal is likely to find a clear path. (From Gruenberg.)

**Nervous Specialization and Control.** The result of this arrangement is that one part of the body comes to dominate the rest—taking the lead and employing for its own purposes, so to speak, the subordinate structures. It needs no long analysis to make clear the necessary effect of such a metabolic hierarchy; we see here the basic mechanism of integration, the coordinating power that makes an individual out of a mass of discrete cells, diverse tissues, and distant parts. Thus, even in organisms so

low in the evolutionary scale that there is absence of definite, polarized nerves, the head rules the body; cephalization (control by the head) has begun; and, as is observed by Herrick, "when the first differentiated nervous system appeared it was laid down in a physiological matrix which shaped the course of its development from the start."

**Differentiation of Tissue.** In a large and complex body the generalized protoplasmic powers of excitation, conduction, and response are no longer adequate to maintain good relations with the environment: Protective integuments render the surface insensitive; transmission over long distances must be rapid and accurate; contraction must be powerful and instantaneous. In higher organisms what is needed and what we find is specialization and division of labor. Time forbids our stopping to examine the intermediate stages—cells with muscular extensions, the syncytial nerve net, and so on—but they are known to exist among the lower organisms in every gradation. Taking their existence for granted, let us see what the evolutionary process has accomplished in connection with the mechanism of behavior.

**Specialization as Nerve and Motor Cells and Tissues—The Receptor-Adjustor-Effector System.** What has happened is this: certain cells have given up their powers in large part and specialized on receptivity to stimuli; others have become primarily conducting strands; still others have made contraction their chief business. Two results follow: (1) great increase in cell efficiency, and (2) increase in cell interdependence. Thus the organism is provided with large possibilities, if only it can make its diversified parts work together. And this it has done through the development of the *receptor-adjustor-effector* mechanism—the nervous system.

**Three Kinds of Nerve Cells.** The sensitive cells (singly or in groups) form sense organs—*receptors*—lying near the surface or otherwise in contact with the environment; the transmitting cells run inward like wires to the central *adjustor* cells which modify and distribute the impulses; the contracting cells, gathered in muscles—*effectors*—at mechanically advantageous places, are activated through a second set of transmitting fibers

from the central cells. It is not difficult to see how such an arrangement, developed in connection with a center of metabolic



Figure 91. Receptor Cells—End-Bulb from the Human Conjunctiva. *n*, axon; *t*, its branching termination within *c*, the capsule. (After Dogiel.)

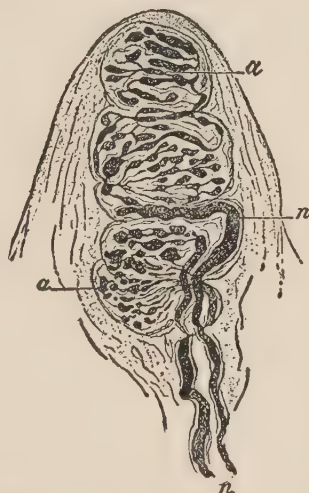
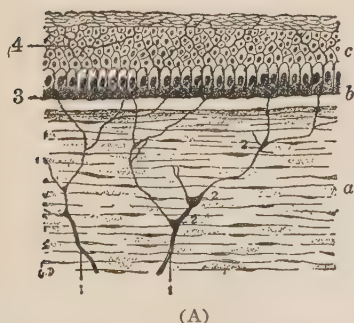


Figure 92. Receptor Cells—Touch Corpuscles from the Hand. *n*, sensory axon; *a*, its branching termination within the corpuscle. (After Ranvier.)



(A)



(B)



(C)

Figure 93. Tactual End Organs. (A) A section of the cornea of the eye much magnified. The small cells in the upper part of the figure show that the tissue is made up of a number of small, compactly arranged cells. A nerve fiber is seen distributing its branches among these cells. This is a typical form of distribution of the tactual fiber, which ends freely in the surface of the body. (B) A Pacinian corpuscle. (C) A Missenian corpuscle. (Each after Testute.)

dominance, can successfully integrate a most complicated individual and keep it in a state of adaptive, though constantly shift-

ing, relations with its surroundings. In fact, it is along the line of development of increasing capacity for coordination through the central or adjustor cell bodies that certain phases of progressive evolution of species may be traced.

**The Neurone Theory.** The nervous system, from earthworm to man, is made up of a *central portion* comprising brain and nerve



Figure 94. The Neurone and its Parts. (After Warren.)

cord, a *peripheral portion* consisting of nerves extending to all parts of the body, and certain other parts with which we are not here concerned. Like other bodily structures, the nervous system is composed of cellular units. These cells are discrete and are specialized for specific nervous activity, as we have seen; in them the original functions of excitation and conduction are highly perfected. A single nerve cell, called a *neurone*, consists of a *cell body* containing a nucleus and having typically two sorts of protoplasmic projections. One of these is called the *axon*. This is a long, slender fiber with a fine tuft at the end. The other is called the *dendrite*. It is a short, many-branched process. The

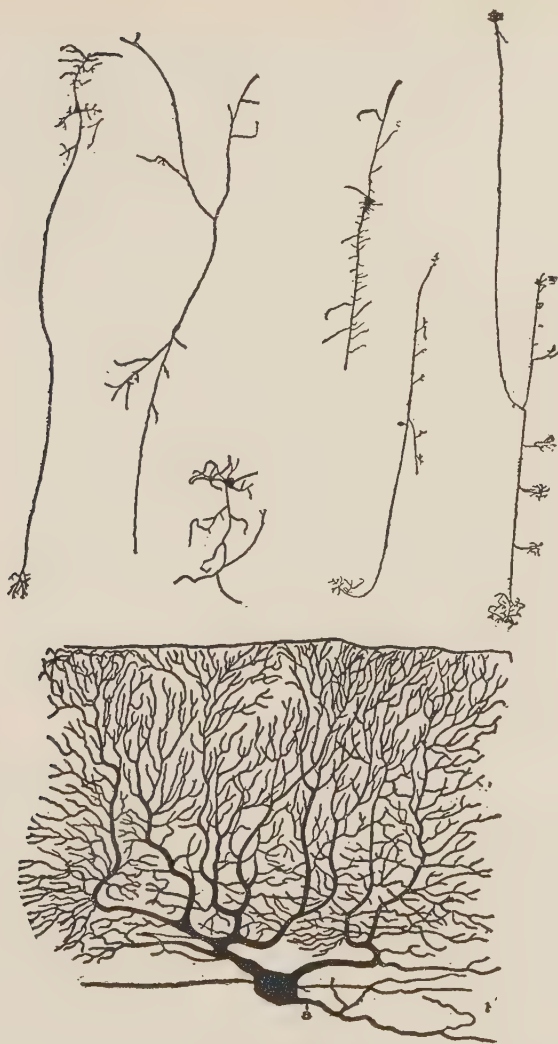


Figure 95. Types of Neurones. Note the relative size of cell body and axon; the thickness of the axon is exaggerated and the finer arborization does not always show in the drawing. Below, a Purkinje cell, greatly magnified. This type, found in the cerebellum, is characterized by elaborate branching of the dendrites; the axon (below to the right) extends beyond the limits of the drawing. (From Thorndike; lower cell after Kölliker.)

cell body nourishes the whole. The axon conducts impulses, often to great distances—as from the tip of the toe to the spinal cord. The dendrite connects one neurone with another. This connection is thought to be accomplished by contact—much as two telegraph wires are joined by twisting—and not by actual fusion. And between the intertwined wires may be tissue that serves much the same function as a “gap” or as “resistance” in an elec-

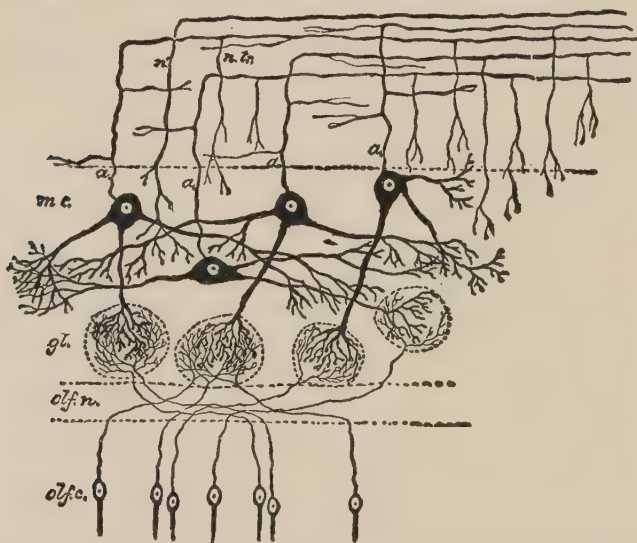


Figure 96. Diagram to show the Connection of Axons and Dendrites in the Olfactory Bulb. *olf. c.*, olfactory cells in the nasal mucous membrane; *olf. n.*, the olfactory nerve, consisting of axons from the cells just mentioned; *gl.*, “glomeruli,” in which the terminal branches of these axons are interwoven with dendrites of cells of the olfactory bulb; *m. c.*, these cells; *a*, their axons, passing further into the brain. (From *Elements of Physiological Psychology*. Courtesy of Scribner’s Sons.)

trical circuit. Where resistance is low the neural impulse readily passes or is transmitted from one neurone to another. Where the resistance is high only the stronger impulses can pass over. This complex mechanistic arrangement is called a *synapse*; and it is evident that the permeability of the synapses will have much influence on the path which nervous impulses are to follow. Each impulse the result of local excitation, will be conducted over the path of least “resistance.” Thereby behavior or the response is determined.

**Automatic Control Mechanism.** As has been said, the anatomical unit of the nervous system is the neurone; the functional unit, basic to the receptor-adjustor-effector system, is the *reflex arc*. In its simplest form this requires only two neurones. One has its cell body near the surface or is otherwise adapted to receive the stimulus; and its axon extends into the central portion. This neurone conducts the impulse inwardly and is called *afferent* (inward bearing) or *sensory*. The other has its

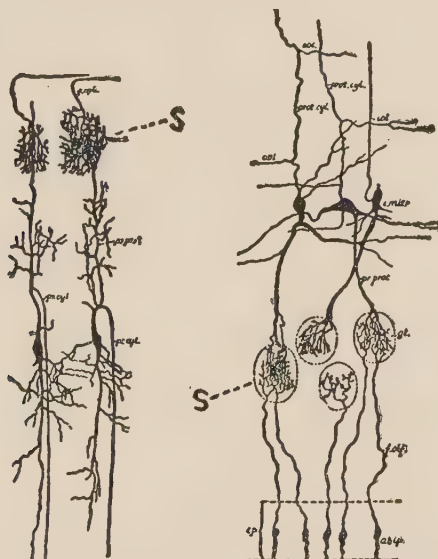


Figure 97. Synapses. Various types of synapses; the synaptic regions are shown at S. (From Thorndike, after Van Gehuchten.)

cell body in the central portion—say, in the spinal cord. It is connected through a synapse with the axon of the first by a dendrite. This second cell called *efferent* (or outward bearing) sends its axon away from the central or spinal region to an effector—i.e., to a muscle or gland. By this arrangement of specialized cells the impulse received and transmitted to the central portion is modified and carried away by the second neurone to a point where a motor mechanism is located. This arrangement of nervous pathways connecting a point of stimulation with an effector constitutes the *reflex arc*. We may think of the

nervous system of a higher animal as made up of a great many such arcs, more or less coordinated and modified in action by a third type of neurone whose function is association. These *association neurones* lie entirely within the central portion, where they



Figure 98. Synapses. A basket cell from the cerebellar cortex of a rat, showing synaptic connections of a single neurone (B) with several neurones (A). A typical synapse is shown at a; b is the terminus of axon; c is the axon of basket cell. (From Herrick, after Ramón y Cajal.)

form connecting links between reflex arcs and between the reflex apparatus and the higher centers, including the brain cortex, in which thought and other controlling processes—the adjustor functions—are supposed to go on.

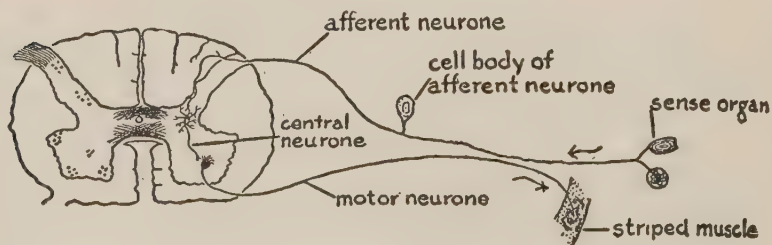


Figure 99. A Short Reflex Arc. (After Watson.)

**Reflex Action.** The reflex arc works automatically, producing the reflex act, as follows: A stimulus reaches some sensitive point on the skin of an animal, causing the afferent neurone to develop and transmit to the central nerve cord an impulse, the nature of which is not well understood. By way of the synapses this impulse is transferred, perhaps with some alteration, to one

or more efferent neurones. In this way it reaches one or more effectors (muscles, for example) which it causes to contract. The result is movement of the body either away from or toward the source of stimulus. By a suitable combination of variously sensitized receptors, appropriately connected association neurones, and a set of motor neurones running to just the right muscles, it is thus quite possible to provide the organism with an apparatus which, without any planning on its part, will automatically insure its performance of approaching or withdrawing acts of such a



Figure 100. Chain Reflex. Stimulation of receptor R, produces contraction of effector E, which stimulates receptor R', producing contraction of E', etc. C, C' are centers. (After Herrick.)

nature as to keep it in favorable adjustment to all ordinary environing conditions.

## Instinct

**The Hereditary Reflex.** Thus, every animal possessing the receptor-adjustor-effector type of nervous system is provided at birth, by heredity, with a set of reflex arcs more or less thoroughly connected by means of association neurones, the whole forming a relatively fixed anatomical basis for characteristic action patterns of the species. As we study this arrangement in a series of animals extending from the lower forms to the highest, we find that the chief modifications which appear are not in the reflex system as such, but in the association centers. Thus in some types practically all activity seems to be stereotyped—adapted to environment by natural selection—while in others the adjustor functions have become so highly developed that reflexes may be allowed, inhibited or modified by the coordinating elements.

**Development of Alternative Nerve Paths in Association Areas.** There seem to be two main lines of evolution leading to behavior of high survival value. By the fixed linking of numerous simple reflexes, either simultaneously or in series (chain

reflexes), the evolutionary process has culminated in the instinctive behavior of the higher arthropods, like the insects and the spiders. By the elaboration of the association centers (the brain) and the development of many alternative nerve paths, any of which may be brought into habitual use by training, the course of evolution has led to the intelligent behavior of the higher vertebrates, including man.

**Instinctive Behavior.** A hunting-wasp emerges from the dark cell where it has developed, innocent of worldly experience, solitary, untaught, untrained. But it is adult, and having mated, it goes at once about its complex business. It digs a



Figure 101. The Development in Complexity of Nerve Cells in the Course of Animal Evolution and in the Course of the Development of a Single Individual. *A* is the nerve cell of a frog; *B*, a lizard; *C*, a rat; *D*, man. The possibility of developing definite paths between various neurones increases in proportion to the increase in the number and complexity of the dendrites from the cells. *a* is a neuroblast without dendrites, from the earlier embryonic development of a human brain. *b* shows the beginnings of dendrites at the upper end of the cell. In *c*, in *d*, and in *e* the dendrites increase. The form of the mature cell is indicated by *D* in the upper series. (After Cajal.)

hole in the sand and fills it with caterpillars so stung as to remain alive, though quiescent. Then it lays an egg on the food material, carefully covers and conceals the nest, and dies. It has never seen its parents; it will never see its offspring. Its activities cannot be attributed to intelligent forethought, for no man or woman could do as much under the same circumstances. Much remains to be learned about the reactions of insects and about their finer nervous structures; but it seems safe to suppose that all this apparently purposive behavior is built up of simple reflexes, so coordinated that one step leads to another according to a fixed scheme—the outcome of many failures and a long evolu-

tionary history. Natural selection has weeded out the wrong combinations, allowing the favorable ones to remain and propagate. Such behavior works well under certain relatively stable conditions of environment; so well, indeed, that not only solitary species like our hunting-wasp can maintain themselves, but even complex societies like those of the ants can flourish and develop institutions that seem, superficially, to resemble and to rival those

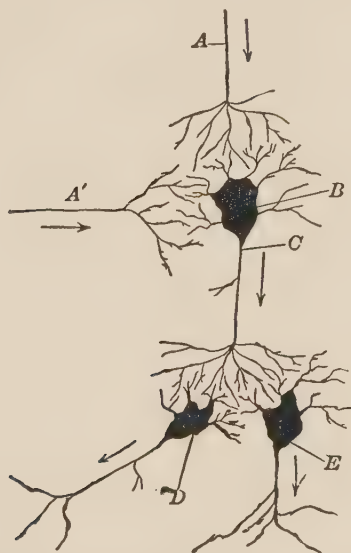


Figure 102. Different Types of Connections between Nerve Fibers and Cells. *A* and *A'* represent incoming sensory fibers which bring stimulations from different directions to the cell, *B*. All of the stimulations acting upon *B* are transmitted along the fiber *C*, and at the end of this fiber may affect various cells, such as *D* and *E*. From the cells *D* and *E* the stimulations may pass in different directions, as indicated by the arrows. The stimulations from *A* and *A'* fuse in the cell *B*. The stimulation in the cell *B* is subdivided and redistributed from *D* and *E*. All connections are indirect, or synaptic. (After Judd.)

of man himself. But let the environment change or the insect be placed in some inhospitable region; or take away the egg just before the burrow is closed—the inherited instincts drive the animal in the same old ways, however unsuitable to the new conditions, and disaster ensues. Some variation is always present, some slight adaptability to new and strange conditions is probably always present, at least in some individuals; but on the

whole, instinctive behavior is fixed and successful only within rather straitly drawn environmental limits.

## Intelligence

**Intelligent Behavior.** The higher mammals have at birth an elaborate nervous mechanism, including many reflex arcs; but it appears that very few of these are independent of brain influence. The structure is there, fixed by heredity beyond any influence that might add or take away units. The possibilities, in any given individual, are quite possibly fixed by anatomical structure; but the behavior of this individual, within the theoretical possibilities, is largely to be conditioned by training. At birth the mammal shows few perfected items of behavior—the higher the animal, the fewer the instincts. Indeed, in the human species the number of innate instincts is much in dispute; psychologists affirm their belief in various numbers from one, say, to sixteen. We may be certain, at any rate, that our behavior depends largely upon learning by experience, which is very different from what we found in the insects, and indicates pretty well what is meant by intelligence.

**Mechanistic Basis of Intelligence.** Let us repeat: the neurones, the reflex arcs in vast number, the machinery of excitation, conduction, and action, all are still present. What is the difference? The answer seems to lie in the extraordinary development of the association neurones, especially the cells of the cortex, the outer layer of the cerebral hemisphere. This structure has two functions: it switches nervous impulses from one track to another, thus modifying and using the fixed reflex apparatus; and it retains some effects from the impulses that pass through it, so that old reactions affect the new, habits are built up, and memory appears. With a complex and highly adjustable structural basis, the capacity for habit formation, and the power of memory, nature has produced an organism fitted to cope with all environments and to enter upon a form of social life that demands above all things *teachability*.

**Heredity and Training.** No one denies that all animals manifest specific, inherited behavior patterns, produced by the

interaction of hereditary neurone structure and a normal environment. In the insects such patterns show little variation, relatively; and the same is true of the lower vertebrates and even of the birds, where the cerebral cortex is little developed. "Psychic traits," i.e., generalizations (such as "wildness" or "tameness") which we make from our observations of behavior, are thus inherited, for they depend upon inherited nervous structure. In the higher mammals and man, where the elaborate and multitudinous nervous pathways of the cerebral hemispheres reach their highest anatomical development, diversity and adaptability and modifiability of behavior are most distinctly present; so that, as already remarked, post-natal development of function (but not of structure) under environmental stimulus is the rule. As a result, it has seemed to some observers that hereditary factors can play but little part in producing the finished individual character. Yet we must not forget the anatomical basis, which is admittedly inherited; and there is much reason to believe that individual horses, elephants, or human beings are born equipped with quite diverse cortical possibilities. Educational psychologists are at present engaged in elaborate studies of tests calculated to bring to light such inherent differences; and as these researches advance it appears increasingly clear that hereditary cortical arrangements are basic to inequalities in such "psychic traits" as musical, mathematical, and logical abilities.

**Human Instinct and Intelligence.** In this chapter we have briefly considered the nervous system as a mechanism of adjustment to envioning conditions. Natural selection has eliminated the multitudinous forms produced by chance mutation, whenever they lacked a minimum degree of adaptation, leaving the happy combinations to reproduce in their own image—again with all sorts of heritable variations, good and bad. Thus, the mean or average of any particular valuable trait has steadily advanced in the direction of fitness, though not necessarily of complexity, or of ideal "betterment." Still, as compared with primitive protoplasm, there has certainly been in many cases an advance in the direction of size and intricacy, leading to an impairment of direct communication with the environment. And it is just here that the need for the nervous system—a receptor-adjustor-effector ap-

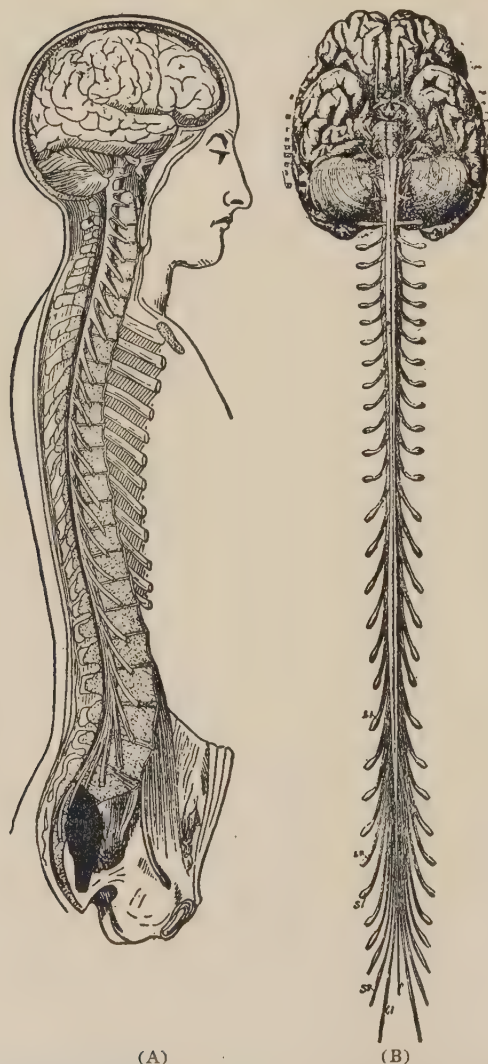


Figure 103. The Brain and Spinal Cord. (A) the brain and spinal cord viewed from the side, in their relation to the general structure of the body;  $1/7$  natural size. (B) the brain and spinal cord viewed from the front,  $3/17$  natural length. (After Van Gehuchten.)

paratus—has arisen. With the appearance of intercalary or association neurones came the opportunity for cranial and cerebral development, resulting in the infinitely adaptable behavior possibilities that have made human social life feasible under the shifting circumstances of every terrestrial environment.

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PART FOUR  
HUMAN NATURE



## CHAPTER XXII

### THE ADVENT OF MAN—HIS CONTRIBUTIONS \*

**A Scientific Approach to the Question of Origin.** Through the substratum of a material world we now come to man. The pre-scientific epics of creation and the data of the physical sciences agree in one respect—i.e., in the belief that man was among the last of the species to appear on the earth. Anthropology is the science which deals most broadly with man—man as differing essentially from other animals. This broad science does not interest itself in the question how man became man, nor does it discuss who man's biological ancestors were. Anthropology frankly admits that after all these years of scientific inquiry, "how and why primitive man alone among primates developed the faculties for speech and culture remains a profound puzzle." But because it does inquire into the cultures, habits, customs, physical and psychological characteristics of primitive peoples, it has much to contribute on the subject of man's origin. The other sciences which have a direct bearing are paleontology, which brings to bear the evidences of fossil remains, and archeology, which deals with ancient cultures. Anthropology is interested primarily in existing primitive races. A scientific approach to the subject in hand should include all these.

**The Eoliths as Evidence of Super-Animal Intelligence.** The first evidence of man's advent and man's upbringing in the rough and tumble of a changing world is revealed by the geologist. Turning the pages of the book of nature, from the period when life first began, he finally came to characters which gave evidence of beings intelligent enough to shape tools of flint so that they could be held in the hand. These traces run well back into the Pliocene geological age. As has been pointed out, some of these implements (eoliths) are found in the buried débris of

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\* By Professor Brightman (see note at the head of Chapter II).

strata laid down before the first Great Glacial Age. How far back in the reaches of time this began we can never know. But from calculations and inferences of geologists whose learning has gained respect, it appears that the makers of these primitive tools may have lived 500,000 years ago.



Figure 104. Relics of Man in the Stone Age. 1, hatchets; 2, hammer head; 3, ax; 4, 5, arrow heads; 6, fish hooks. (From Gruenberg.)

**Three Aspects in Which Man's Development May Be Studied.** Anthropology takes these evidences into account, as well as the findings of the archeologists. As a science it recognizes three quite definite and different kinds of evidence which bear on the subject of man's past. These for the present purpose may be called physiological, psychical, and social. The factual basis for the first is found in fossils—the bony structure of pre-existing beings which scientists identify as belonging to the human race; the second deals with the evidences of psychological activity which differentiates human beings from non-human—prim-

itive culture; the third deals with those dispositions, habits, customs, conventions which we think of as human—as distinguished from non-human social arrangements. In scientific literature the first may be thought of as a specialized branch of comparative anatomy; the second may be thought of as a specialized branch of psychology—but this as furnishing a point of view for the study

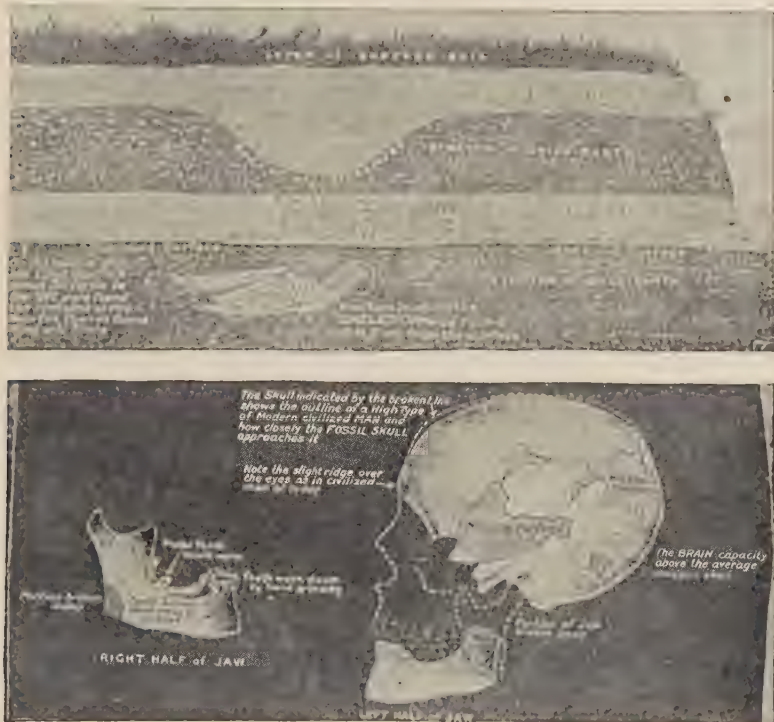


Figure 105. Fossil Remains. The skull of a modern type man, found at the Halling burial place. (From Churchward.)

of mythology, demonology, and primitive religions; the third may be thought of as a specialized branch of sociology.

### Man's Fossil Remains

**Comparative Anatomy as a Side-Light.** Comparative anatomy is a branch of science largely used by the paleontologist in interpreting the records of the rocks as these have to do with the

variations of life structure—the adaptations of species through the ages of geological times. Thus the geologist has traced the horse from age to age. He begins in the Eocene period when the species had five toes and was about the size of a dog; from this beginning he traces changes from age to age—as complex causes have modified the horse structure—to the period in which we now live. Many species have been similarly traced in

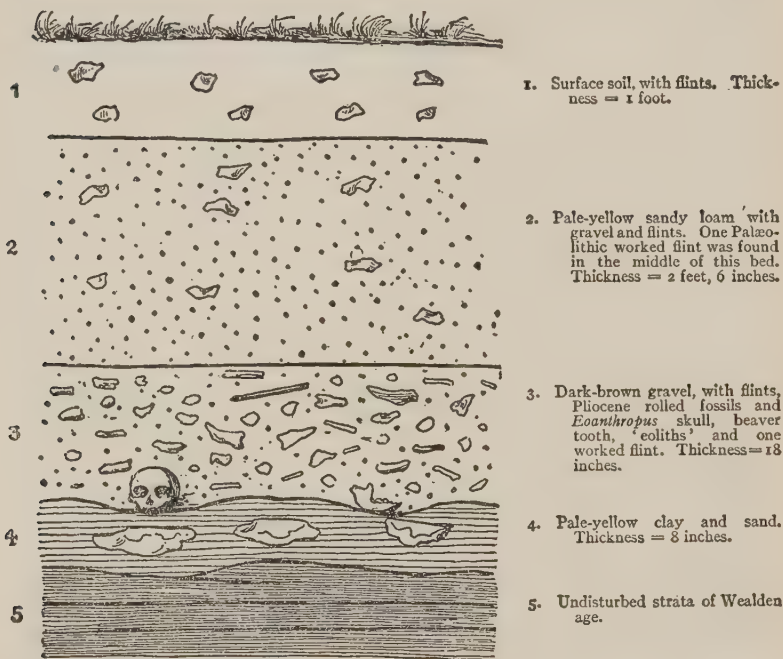


Figure 106. Geologic Section of Piltdown Gravel Bed, Showing Remains. (From Osborn.)

fossil remains. This same method reveals man, anatomically, as far back as the Second Interglacial period (perhaps 200,000, or 250,000 years ago), a being of structure strikingly like our own and with a cranial capacity far exceeding any non-human species. The oldest of fossils which closely resembles the human is called *Pithecanthropus erectus*. This is believed to be a type intermediate between man and ape—a creature who walked erect in the Pliocene period, probably half a million years ago. Among the notable discoveries of the more highly developed human head

in the Second Ice Age is one known as that of the Heidelberg man. This particular fossil is too fragmentary to warrant sweeping generalizations; but other remains are identified as of a similar type.

**The Piltdown and Neanderthal Man.** Among the fossil records of a geological period much more recent (the Third Inter-glacial—estimated by Pench to have begun about 100,000 years ago and to have lasted 50,000 years) were found fragments of a skull at Piltdown, England, belonging to what is known as the Piltdown man. This skull more nearly approximates the size and mental capacity of a modern man. Other remains have been discovered at widely separated points, as England, Germany, Java, and Africa. Among these is the Neanderthal man discovered near Düsseldorf. (This is thought to be 50,000 years old.) In this brief sketch the fossil remains of man need not be discussed more than to call attention to the fact that beings having the likeness and the brain capacity peculiar to man existed in the days when the woolly elephant, the hairy rhinoceros, and the great reptiles were among the species to which Dame Nature gave common burial; and that with these remains are found many of the implements used by this super-intelligent being whose survival depended on his wits.

### Primitive Psychology

**Man's Mental Growth.** Science tells us in unmistakable terms a story of man's mental growth. The capability of *homo sapiens* has unquestionably increased. That this is so is not only evidenced from the testimony of the geologist; it is written into the record of prehistoric cultures. It is also written into the scientific literature in which the mental states and activities of primitive races are compared with races and peoples now advanced in civilization. By studies of this kind we have come to know some of the traits common to human kind, and the differences that distinguish the mentality of primitive people from our own. The subject is too large for us to enter upon in its philosophical and controversial aspects. Enough may be said, however, to distinguish the primitive from the sophisticated mind.

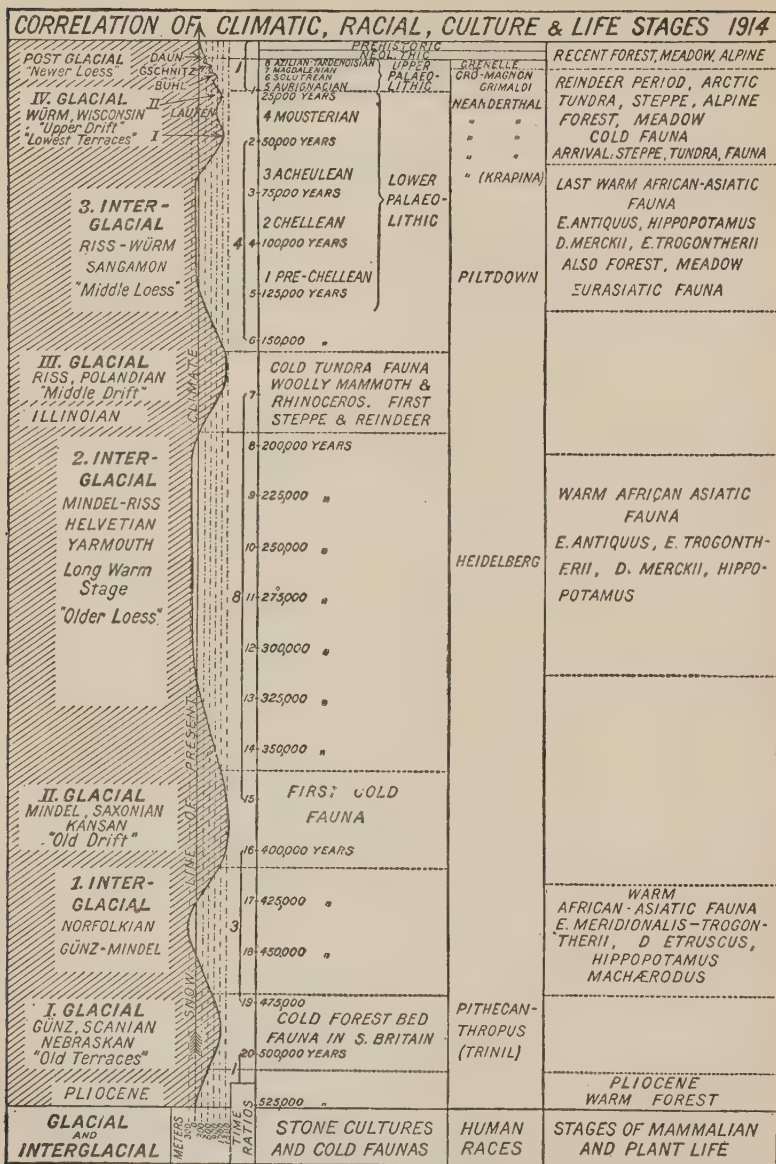


Figure 107. Table Showing Climatic, Racial, Cultural, and Life Stages of the Glacial Epoch. (From Osborn.)

**The Primitive as Reproduced in Children.** One of the most fruitful sources of scientific information about the growth of mind (both in its physiological and psychological aspects) is in studies of the mental development of children. There is a resemblance between the mental state of the child and of the primitive man. Both are highly imaginative. Both are highly motivated by fear, aroused by the unknown. Neither has a wide range of experiences to give balance to reason and judgment. Both have a feeling of dependence. While the child confides in parents and elders of his group, primitive man weaves his dreams, and imaginings (unbalanced by trial and error experience) into mystical conceptions that become the premises of conventionalized reasoning to him. And this comes to form the principal culture transmitted from generation to generation—reinforced by the customs of the tribe. Lévy-Bruhl in his book on *Primitive Mentality*, after discoursing on the distaste of the primitive for discursive thought, and on his regard for dreams, omens, divination, ordeals, and mysticism, arrives at this conclusion: "An analysis of the preceding facts—facts which can easily be confirmed by many others, . . . leads yet again to the conclusion that the primitive's mentality is essentially mystic. This fundamental characteristic permeates his whole method of thinking, feeling and acting. . . ."

Every individual starts with the experiences of infancy and childhood which cannot be or have not been scientifically recorded. So, too, the race took its beginning at a time which is pre-scientific—it has had its stage of primitive life. When we seek to discover just what was the state of mind of the earliest human savages, first emerging from their sub-human ancestry, we are baffled both by the insufficiency of the evidence and by our incapacity to enter into a sympathetic understanding of a mental life so foreign to our own. There is difference of opinion among anthropologists about the amount of reasoning of which primitive man was capable. Some hold that he was mostly in a state of reverie; their thought is that he was guided merely by an association of ideas without any critical thinking. Others see a rather high degree of intellectual activity, however greatly that activity may differ from our own.

**Psychological Studies of Sub-Human Species.** Recent studies of Köhler and Yerkes make it appear that even apes can reason. The former carried on a long series of experiments, observations and records of what he considers mental reactions in apes, in the use of tools, choice between alternatives in the solution of problems, etc. Yerkes' experiments are of the same general nature. Holmes has made much wider but less intensive studies of animal intelligence. If we accept the conclusions of these scientists it is probable that thinkers like Lévy-Bruhl have underestimated primitive mentality.

**Beginnings of Thought in the Human Species.** Be that as it may, there is a wide gap between scientific thought and primitive thought; in methods, in aims, in estimate of what is real or unreal, important or unimportant, there is little in common between the two. In one aspect, however, all reflective thinking is the same. Reflective reasoning requires a certain detachment from things external. The mind must be in considerable measure freed from consciousness of sensation. It must refer to pictures of past experiences (memories) and to imaginings unhampered by the limitations of stimuli aroused by present actual contacts with environment. Thereby man is able to create his own world—to live in reveries and dreams and in a thought world.

**The Place of Reveries in Association of Ideas.** The mind continues active while the motor mechanisms and sense organs of the body lie dormant or are in a state of repose. It is then, if at all, that conscious experience records itself in reveries—in associations of ideas which themselves serve to stimulate a flow of nervous energy along interrelated brain paths; and by a process of growth in the plastic tissue, in response to these pressures, new brain paths may be made. Thereby the thinker may become conscious of conditions and relations not before known—may solve problems which before have not been solvable to him. It is in the reveries and in the thoughts of primitive man that civilization must have had its roots.

**The Function of Primitive Thought.** Whatever the aims and function of sophisticated thought may be, the biological end of primitive thought was to secure to the thinker survival for

himself and his group. As soon as man became conscious of reflective reasoning he must have prized life; he must have been aware of a mysterious something which differentiated the living from the non-living. Obviously, the function of primitive



Figure 108. The Soul Bird.  
(From Gray.)



Figure 109. The Dead Visits His  
House. (From Gray.)

thought, as well as of highly developed scientific reasoning, has been to aid the thinker to make choices between pictured alternatives without incurring the risk and waste and loss of making random adjustments to eventual experiences, and thereby to preserve and enhance life. There was a conscious longing to enter into relations with powers which were aids and sources of life.



Figure 110. The Soul Returns to the  
Grave. (From Gray.)



Figure 111. The Soul Returning to  
the Body. (From Gray.)

**Animism.** Out of this estimate of life grew the widespread primitive belief that there dwells in many natural objects, trees and wells, springs and winds, a life in some way akin to human life, with a power akin to human will. This general belief is called animism (*cf.* the reference to *Mana* in Chapter II). The principle of life was called by terms more or less equivalent to

our word "soul" or "spirit." But primitive thought was not long satisfied with mere animism. Animism held that the soul was "bound" to the object in which it dwelt.

**Spiritism.** Experiences of dreams, of death, of shadows, and of such phenomena as interest modern societies of psychical research, soon led primitive man to the belief that man's soul was not bound to its body, but could depart from it, temporarily in sleep, permanently in death. Generalized, this meant that all souls or spirits are capable of moving freely about, and leaving or entering at will the objects which they inhabit. The purely animistic stage is not known to survive today; but many of the lowest races, such as the Bushman of South Africa, are spiritists. Indeed, some recent scholars doubt whether animism was so widespread as our statement has put it. Spiritism may be the earliest type of thought.

**Totemism.** Connected with spiritism is a belief known as totemism which is to be found in almost every region of the globe. We naturally think in this connection of the Alaskan totem poles. But the totem is not a pole; it is an animal, which is supposed to stand in intimate relation to the tribe. The eagle or reindeer or turtle, or whatever the totem animal may be, is not only venerated by the tribe, being killed and eaten only at sacred and sacramental feasts, but is also usually regarded as the ancestor of the tribe. Thus, totemism symbolized tribal unity and the unity of human and non-human ("divine") life, as well as serving to differentiate each tribe from tribes with different totems.

**Belief in Good and Bad Spirits: Magic and Religion.** The world of primitive man thus came to be densely populated with spirits. These spirits seemed to be in themselves neither good nor evil, but rather powerful and reckless. It was believed that there were certain ways of compelling spirits to benefit human life; the technique of such compulsion is what we call magic. It was also believed that spirits might be persuaded or propitiated; the ritual and attitudes of such persuasion were the roots of religious formalism. The influence of spirits was believed to be a matter of daily experience, affecting the crops and hunting, health

and sickness, life and death. Desire for protection from harm was doubtless an important source of burial customs, which led men to supply the spirit of the departed with provisions for his journey in the other world. Through witches, medicine men (shamans), or other supernaturally endowed persons, the spirits of the departed might be consulted, as in the Biblical narrative the witch of Endor summoned Samuel's spirit for Saul. But departed human spirits were not regarded as being in the same category with superhuman spirits.



Figure 112. Witches in Flight. (From Thompson.)

**Abode of Good and Evil Spirits.** As civilization advanced, and thought both about spirits and about the world (see Chapter II) became more clearly outlined, there was a general tendency to distinguish more sharply between good and evil spirits and to assign one common dwelling place to the good spirits and another to the evil ones. The evil spirits were supposed to dwell below the earth (Hades), while the good spirits had a lofty abode, usually on the top of some mountain (Olympus, the mountains of the North, etc.) or in some mysterious place above the sky. Several interesting diagrams or attempts to picture the relations of the abodes of good and evil spirits have been prepared. Among these are the pictures of Himes, Masson, Sprague and Orchard,

graphically describing what Milton had in his mind when he wrote *Paradise Lost*; <sup>1</sup> Caetain's pictures of Dante's conception of Heaven and Hell; and Whitehouse's graphic interpretation of the conception of the ancient Hebrews as reflected in the first chapter of Genesis (see *Creation Epics*—Chapter II).

**Demons.** There was a marked tendency in early times (which still exists among savages) to pay more attention to evil spirits (demons) than to good ones. This may be due to the confidence that good spirits could be trusted to behave themselves, while evil ones needed attention; or it may be (as Jevons suggests) because demons were not attached to a clan and so were under no obligation to be "good," as was the totem. However that may be, all of the misfortunes of man—diseases, storms, failure of crops, defeat in war—were attributed to demons. Primitive man stood in the presence of forces beyond his power to control or understand. It is not surprising that he attributed them to evil spirits.

**Beings "Possessed" by Demons or the Devil.** It was believed not only that demons could affect the outcome of human undertakings, but also that demons could enter into human beings and "possess" or control them either temporarily or permanently. The facts of abnormal psychology, or hysteria, epilepsy, catalepsy, somnambulism, hypnosis, insanity, and the like give the primitive mind what to it is sufficient evidence of the presence of evil spirits and their "possession" of man. The New Testament contains descriptions of these states. A father says that his son has a dumb spirit, which "dasheth him down and he foameth, and grindeth his teeth and pineth away" (Mark 9:17-18). Similar phenomena in the Orient today are still ascribed to demons. So persistent is the belief that some European and American missionaries are influenced by it and avow their acceptance of it. But modern science is unanimous in ascribing cases of "demonic possession" to mental disease or abnormality. The influence of the scientific view on religious thought is evidenced by the fact that the page-heading above the narrative just quoted from Mark reads, in the American Standard Version of the Bible, "Epileptic boy cured," and not "Dumb spirit cast out." Belief in demons

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<sup>1</sup> Appendix to *The Universe as Pictured in Milton's Paradise Lost*, by W. F. Warren, Abington Press, 1915.

has, then, been banished from the modern mind by the advance of scientific knowledge. But for many centuries mankind lived in fear of these invisible foes, and sought ways to placate them. Traces of "devil-worship" still exist, even among civilized peoples. But parallel to the growth of demonology, religion developed out of spiritism, and to that development we now turn.



Figure 113. A Bishop Exorcising a Devil—from a XV Century Woodcut.  
(From Thompson.)

**Polytheism—Its Cultural Significance.** Andrew Lang and some others hold that primitive man had at the start a conception of one Great God or High God, which later was forgotten. This view, however, is rejected by many anthropologists and historians of religion in favor of the theory that the belief in many gods (polytheism) preceded the belief in one supreme God (monotheism). Just as spiritism first gave rise to the belief in many demons, and Satan, the chief demon or the devil, appeared later, so also the belief in many gods preceded the belief in one supreme God. The period in the development of culture at which polytheism arises out of spiritism is reached when the mind has become clearer and more analytic than in primitive times. Good

and evil are more sharply distinguished; nature is more accurately observed and civilization has become more highly organized.

### **Idealization and Deification—Faiths That Have a Social Value**

**Beliefs in Gods.** The beliefs in gods—friendly supernatural beings, worthy of worship—arise, then, out of spiritism by the personification of observed facts and forces. In particular, three typical sets of facts are thus personified or deified: (1) natural objects and forces, (2) forms of social organization, and (3) great men. The inspirational value of these three modes, expressions, or patterns of thought, has been such that they should not be passed over without comment.

**Deification of Natural Objects and Forces.** Among natural objects and forces deified were the sun and the moon, the ocean, rivers, wind, thunder and lightning, the soil, seed, trees, grain—in the main, those things whose action must be taken into account by primitive man when making plans or seeking to realize his purposes. These were woven into various systems of mythology—Grecian, Roman, and what-not. This principle also entered into the various forms of religious worship evolved by the most primitive peoples.

**Deification of Social Organization.** Forms of social organization were also deified. Each tribe or nation had its patron deity. The Jahveh of the Hebrews, it is true, commanded that "thou shalt have no other gods before me," and thus was on the way to monotheism. But since the very commandment just cited assumes the existence of other gods, early believers in Jahveh were henotheists rather than monotheists; that is, they believed that many gods existed, but that only one was to be worshipped. As nations were organized into world empires, there was a social basis for the idea of a single God of all the world. This happened in Roman times, notably among the Stoics. But the personification of social organization did not lead solely toward unity; it also led toward multiplicity. As society became more and more complex, it was divided into more and more professions and

trades, and each profession, guild, or "labor union" developed its own deity. The physicians, the warriors, the farmers, and many other classes were patronized by special gods. Each home had its own *Lares* and *Penates*. Thus social development tended toward both diminishing and increasing the number of gods.

**Deification of Great Men.** To some extent great men were regarded as divine and worshipped as gods. One of the great religious struggles of history was between the official religion of the Roman state, which deified the Caesars, and the Christian religion, which regarded Jesus of Nazareth as divine. Neither Buddha nor Confucius claimed a divine nature, yet each has been worshipped by his followers. The general tendency to deify great men is indicative of a high valuation of individual human personality by society, and thus presupposes a certain development of individualism.

**Pantheism.** We have in polytheism itself a certain tendency toward unification of the gods into one supreme deity. The tendency toward unity also has expressed itself as pantheism—the belief that nature as a whole is God, and that, therefore, God is in everything and all is divine. The tendency to find one all-inclusive God is to be traced in Egypt (where the sun-god was made the all-god), in India (where Brahma is the absolute one), and in the Eleatic and Stoic philosophies of Greece, as well as in certain forms of modern absolutism. While this pantheistic development had the natural effect of making the idea of God vague and of blurring moral distinctions where everything was divine, nevertheless it performed the cultural function of setting up an ideal of social and cosmic unity. It was, therefore, not unrelated to the aim of scientific thought, which is to discover unifying principles in the apparent confusion of experience. Moreover, while pantheism often has tolerated the popular worship of polytheistic deities as symbols of "the One," its logic points away from polytheism to belief in one God. In the chief religions in which belief has assumed the form of monotheism rather than of pantheism, there is the conception of a single supreme spirit who is creator of all but who is not identical with his creation.

**Monotheism.** We have observed in the conception of the Spirit World two pairs of main tendencies: one toward evil spirits (demons) with an opposing tendency toward good spirits (gods); and one toward multiplicity and supernatural beings, with an opposing tendency toward a singly unified spirit. In monotheism the tendencies toward good and unity triumph over the tendencies toward evil and multiplicity. As society becomes more thoughtful, it develops its moral, esthetic, intellectual, and religious ideals. Men are led to see—as Plato brought out in his *Republic*—that the gods of polytheism are morally inferior to the best men, and that it is unreasonable to worship any being who is less than perfect. While religion is in certain respects conservative and resistant to change, it is also in other respects a radically progressive social force, especially when “prophets” arise who criticize the social order and existing religion in the light of higher moral ideals. Through such a process of criticism by men like Zoroaster and Buddha (although his criticism of belief in God was mostly negative), Xenophanes and Plato, Isaiah and Jeremiah, and, most significantly, by Jesus of Nazareth, religion has developed the belief in a single God who embodies all of the highest ideals of human society. The omnipotent, omniscient, personal God of monotheism, like the God of pantheism, controls all the mechanisms of the universe; the laws of nature are his laws. But, unlike the God of pantheism, he rises above those mechanisms and uses them for his universal purpose. This is the conception at which reflective religious thought has, in the main, arrived in most of the great world-religions. “All’s law, yet all’s love,” is the way in which monotheism is concisely stated by Browning.

**Mythology.** The development of the idea of a spirit world has been clad in the garb of mythology. Names of the gods, places frequented by them, incidents in their careers, have become standardized and are made the basis of everyday conversation as well as of the language of poets and priests. Mythology, however, does not exist in the most primitive animism and spiritism. Only as gods are worshipped and are definitely believed in is there a myth-making activity. Up to a certain limit set by science and reflective thought, it may be said that the richer

the civilization, the richer and more abundant are its myths. Myths are occasioned by spontaneous primitive imagination, by the need of definiteness and warmth in the objects of worship, by the conventions of ritual, and also by the desire for cosmological explanation (see Chapter II). Since many different factors entered into their formation, and since they have been a slow growth carrying with them accretions from many stages of culture from the lowest to the highest, myths contain many extravagances and contradictions. Often the most ridiculous and immoral acts are attributed to the gods, along with noble and ideal traits. Since they deal with a realm which lies beyond experimental investigation, myths are difficult to refute; they die when the intellectual climate becomes too severe for them.

**Mythos and Logos.** Two Greek words, *mythos* (myth) and *logos* (word or reason) are often contrasted with each other to bring out the true function of myths. The *mythos* is the picture or symbol, the *logos* is the principle or truth which the *mythos* illustrates. This statement should not be taken to mean that myths were made with the deliberate intention of teaching abstract ideas. They grew far too spontaneously and naively for that. But, after all, there is a certain naive reasonableness at work in the age-long products of the social mind; and a study of myths reveals their function as attempts to explain and unify the facts with social and natural experience. They are morally and scientifically unsatisfactory, but they express the fact that man desires the *logos*, the explanation of his work, a task with which the modern mind is struggling.

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3. What is the science that deals most broadly with man; how are the sciences of anthropology, social psychology, morphology, sociology and ethics related?

(See Encyclopedic discussion of these subjects.)

4. How widely distributed and through what geological periods are fossil remains of man to be found?

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19. What is the meaning and cultural significance of polytheism?

Galloway, *op. cit.*, pp. 113-115.  
 Tylor, *Primitive Culture*, Vol. II, pp. 247-252, 304-334.  
 Edwards, *op. cit.*, pp. 104-106.  
*Ency. Rel. and Ethics*, Vol. X, article "Polytheism."  
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20. How do we distinguish between the beliefs and superstitions of primitive people and those beliefs in gods or God which were held after social consciousness had become more highly organized?

Galloway, *op. cit.*, Ch. II, Beginning and growth of religion, pp. 88-152.  
 Radin, *op. cit.*, Ch. XVII, Nature of God, pp. 329-341; Ch. XVIII, Monotheistic tendencies, pp. 342-374.  
 Edwards, *op. cit.*, Ch. IV, Historical development of religion, pp. 93-134.  
 Hopkins, *op. cit.*, Ch. XIV, Religion and mythology, pp. 226-244.

21. What are the three main divisions of the objects of deification and faiths that have a social value? Give illustration of deification of nature, objects, and forces.

Hopkins, *op. cit.*, Ch. II, Worship of stones, hills, trees and plants, pp. 13-31; Ch. IV, Worship of elements and heavenly phenomena, pp. 47-57; Ch. V, Worship of the sun, pp. 58-66.  
 Tylor, *Primitive Culture*, Vol. II, pp. 204-229, 254-303.  
 Thomas, ed., *op. cit.*, pp. 730-732.  
*Ency. Rel. and Ethics*, Vol. IX, article "Nature," pp. 202-207.

22. Give illustrations of deification of social institutions and organizations.

Edwards, *op. cit.*, pp. 40-44, 109-112.  
 Durkheim, *op. cit.*, pp. 285-296.  
 Galloway, *op. cit.*, pp. 96-97, 105.  
 Hopkins, *op. cit.*, Ch. XI, Sacrifice, pp. 151-179; Ch. XII, The ritual, pp. 180-203; Ch. XIII, Priest and the church, pp. 204-225; Ch. XIV, Religion and mythology, pp. 226-244.  
 Read, *op. cit.*, pp. 293-296, 307-311.  
 Tylor, *Primitive Culture*, Vol. II, Ch. XVIII, Rites and ceremonies, pp. 362-442.

23. Give illustrations of deification of ancestors and great men.

Tylor, *Primitive Culture*, see index "Ancestors, worship of."  
 Hopkins, *op. cit.*, Ch. VI, Worship of man, pp. 67-72; Ch. VII, Worship of ancestors, pp. 73-87.  
 Galloway, *op. cit.*, pp. 95-96.  
 Edwards, *op. cit.*, Universal religion, pp. 123-134.  
 Thomas, ed., *op. cit.*, pp. 714-718.  
*Ency. Rel. and Ethics*, Vol. I, article "Ancestor-worship."

24. What is meant by pantheism?

Galloway, *op. cit.*, pp. 460-466.  
 Edwards, *op. cit.*, see index "Pantheism."  
 Hopkins, *op. cit.*, see index "Pantheism."  
*Ency. Rel. and Ethics*, Vol. IX, article "Pantheism."  
*Ency. Britannica*, Vol. XX, article "Pantheism."  
*New Internat. Ency.*, Vol. XVIII, article "Pantheism."

25. What is meant by monotheism—how is it related to pantheism?

Hopkins, *op. cit.*, pp. 281-285, 287-290.  
 Edwards, *op. cit.*, see index "Monotheism."  
*Ency. Rel. and Ethics*, Vol. VIII, article "Monotheism."  
*New Internat. Ency.*, Vol. XVI, article "Monotheism."

26. What is the scientific place and importance of mythology; how is mythology related to the natural sciences?

Tylor, *Primitive Culture*, Vol. I, Ch. VIII, article "Mythology," pp. 273-315.  
 Edwards, *op. cit.*, pp. 106-108.  
*Ency. Britannica*, Vol. XIX, article "Mythology."  
*Ency. Rel. and Ethics*, Vol. IX, article "Mythology."  
*New Internat. Ency.*, Vol. XVI, article "Mythology."

## CHAPTER XXIII

### MIND—ITS EMERGENCE AS A MECHANISM OF ADJUSTMENT

#### THE INTRODUCTION OF MIND INTO THE ADJUSTMENT PROCESS \*

**The Nervous System and Adjustment.** Chapter XXI has shown us how animal species have been equipped by nature with a nervous system as a specialized mechanism by which they are able to make favorable adjustment to their environment. This chapter deals with the higher development of the mechanism of adaptation in man. Every animal, and plant too, for that matter, has the problem of continual adaptation. But each species has a different way of solving such problems. Each organism gets more or less help from others—the well-being of each individual and each species being contributed to by certain functions performed by other individuals and species.

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*Editor's Note:* One of the best definitions of general intelligence is "the ability of the organism to adjust itself adequately to new situations." What Professor Bernard calls mind would seem to be definable in the same terms—a functioning of the nervous system in which memories or a modification of the nervous system through past experience in part determines the nature of the adjustment.

Reading references are given to the writings of scientists, as John Muirhead Macfarlane, Professor of Botany and Director of the Botanic Garden at the University of Pennsylvania, and Henri Bergson, Member of the Institute and Professor at the College de France (see Mitchell translation of *Creative Evolution*). Macfarlane presents the view that all protoplasm has the capacity common to colloidal substances, of selecting materials which operate to produce growth, etc. The selective process carried on by protoplasm achieves certain results not achieved by non-living colloids: that of organizing more complex molecules—substances such as proteins, fats and carbohydrates which have high potential energies; of reducing molecules of high potentiality to those having

The simplest mechanisms of selection and adaptation are found in unicellular organisms, many of which are microscopic. Among multicellular plants the problem of adjustment is more simple than among animals. Plant life mechanisms are adapted to leading a sessile life. With them continuity and abundance are almost wholly matters of relatively simple biophysics and bio-

lower potentiality and thereby releasing energy; and of adapting the mechanisms in and through which this is done so that "varied environmental stimuli are linked into a summated and unified response, that brings each organism into satisfied relation to environment." This he calls the law of "proenvironment." The forces developed by organisms are said by him to be a new or different manifestation of energy which he calls "biotic," to distinguish it from those forms manifest in inorganic mechanism called "gravic" (manifest as weight), "thermic" (manifest as heat), "luminic" (manifest as light), "chemic" (manifest in chemical change), "electric" (manifest in electric currents, magnetism, etc.). And "biotic" energy is further specialized in manifestations of characteristic protoplasmic mechanisms as: "cognitic" (having capacity for consciousness); "cogitic" (having capacity for reflection and the exercise of intelligence in making choices); and "spiritic" (capable of responses and development we call spiritual, as distinguished from mental and physical). Bergson writes to the theme that nothing can manifest itself which is not present, and therefore the characteristics of intelligent beings must have existed in the universe before man—or even the lower organisms. There is no desire to urge the acceptance

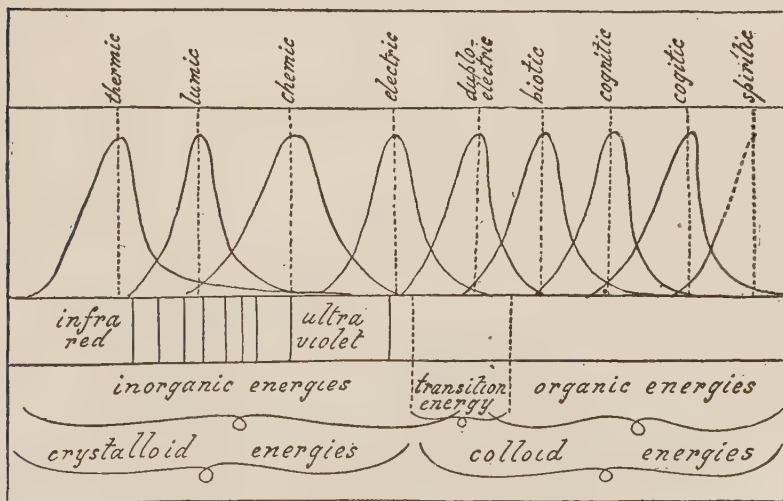


Figure 114. Table of Energies. (From Macfarlane.)

of any scientific or philosophic school in this symposium—only to give to the reader the findings and conclusions of the different scientists. In this relation the purpose is to point to the conclusion that both the capacity for selection and specialized mechanisms in which selections were made, existed before the advent of the human race.

chemistry. Few of the plants have problems of motility to solve; consequently they have no nervous system, properly speaking. The wider range of cooperation among animals which live in like environments is discussed in Chapter XIX. Among human kind the relationships and systems which provide for mutual aid and protection are called society. This is the subject matter of various specialized bodies of information—anthropology, sociology, social psychology, and the other social sciences. All these related subjects of scientific inquiry take on a new interest and meaning different from the non-human biological specializations, because the human species has developed a higher order of selective and directing equipment. Thus only the human species, whose members live social lives, has accommodated itself to the need for progressively higher forms of cooperation through an enlarging intelligence developed by interstimulation and response. Communities of human individuals have proved themselves capable of reflective reasoning about experiences and of communicating the results of experience, also of recording experiences and their results and transmitting these from individual to individual and from generation to generation. Human individuals and groups not only have the advantages of many of the inherited specialized mechanisms of adaptation that have been developed by non-human ancestral species, but in addition they have come to possess the mechanisms of intelligent control for holding the lower or more primitive processes in abeyance until an account can be taken of the conditions present which have given rise to the problem or dilemma to be dealt with. Human beings alone have developed in marked degree processes of reflective reasoning.

**Why Man Makes Superior Adjustments.** Lower animals have developed nervous mechanisms, but they are simple as compared with the wonderful neural apparatus inherited by man. As a consequence of the relatively inferior equipment of the non-human species, they have died off in great numbers where in like circumstances man has become the master of his own destinies. The non-human species have been forced to accept conditions as they are and to assure continuity through adaptation of their own organisms to the environment in which they live—or perish. Man has developed a capacity for modifying conditions, external

to and not a part of his organism, which are favorable to his well-being. Non-human beings may perish from hunger where natural supply fails; man "raises" or "manufactures" his own food. Non-human beings die from disease under conditions in which men, with their superior knowledge, are often able to protect themselves. Animals die of exposure; men are able to provide themselves with clothing adapted to changing conditions of temperature and weather. Instead of being limited to a particular zone, they may live and prosper in all zones. Few men die of hunger. Many human beings still suffer from want. Many have their vitality lowered by privation, and others by luxury and over-feeding. But the cure for these conditions is within reach when the organized intelligence of communities is brought to bear upon the problems. Many human beings are still destroyed by disease, especially those associated with minute, hostile organisms popularly called "germs." These propagate and thrive in conditions that give rise to what are sometimes called filth diseases—again a matter of lack of attention to adaptations necessary to wholesome living. Civilized man is the victim of many degenerative diseases that persons in a state of nature do not have. These are due to ignorance, or to the wilful disobedience of the laws of health. Less than one hundred years have elapsed since Pasteur began to teach human kind about the most dangerous of all man's competitors for existence, the microscopic organisms or "microbes." Considering the length of time man has known about these "enemies," he has made much progress in controlling even this phase of his environment. Because of his ability to make superior adaptations man has come to be the most widely distributed of all the species.

**Capacity for Understanding.** Non-human beings are inferior not alone in their inherited specialized equipment for adaptation, but also in the intelligent use of the equipment with which they are endowed. They possess no culture and they lack the intellectual power of choosing the better of two or more possible ways of acting. They have no capacity for thinking in terms of utility, i.e., in terms of the adaptability of a thing or social arrangement to fit a felt need. Non-human beings have no intellectual "appreciation" either of the natural world in which

they live or of the ideas entertained, communicated, and passed on by man for his guidance. Consequently they are able to respond to their limited environment and adjust themselves to it only instinctively and on the basis of very simple habits. Because of his greater intellectual ability, man not only senses (sees) things in his environment that animals do not, but increasingly man perceives (sees through) the significance of things and happenings for his better adjustment. Man has made much progress, especially in recent times, in the direction of a better understanding of his environments. With this understanding he has become capable of seeing things afar-off in time as well as in space. He has not only learned to see the more obvious things that are readily visible and near him on every hand, but he has also acquired the power of seeing and understanding the distant in time and space, and even the invisible. What to non-human beings are points of light, to man are heavenly bodies. Other animals are aware of only that which is within the range of their senses, but man's understanding embraces distant objects, men, cities, civilizations beyond the direct range of his senses. Only man can reconstruct the social past. He alone seeks to "universalize" his environment and to comprehend that which is not sensed. And only he possesses history.

**Capacity for Invention.** Being able to "evaluate" things—to think reflectively in terms of conscious purpose and of means to an end—man is able to invent. In this way he has greatly improved his adjustment to his world. For example, he has invented instruments by means of which he sees things which animals cannot see at all. By using his mind for purposes of "thinking" as well as "seeing" or "perceiving" he is able to understand things, like the electrons and electricity which he himself cannot see. By that most basic of all inventions, language, each human being is able to make known his experiences and wishes and to know what is going on in the minds of a whole community. He is able to reflect and to predict; he is able to look back into the past and forward into the future; he can "see" things that happened long ago and other things that his reason tells him are likely to happen sometime in the future. As a higher development of the specialized mechanisms of adjustment

mentioned above, these are wonderful powers; no other animal has ever possessed them. They make men like gods, to use a telling expression of H. G. Wells.

**Capacity for Far-Thinking.** What is this remarkable thing which enables man to do so many wonderful things of which no other animal is capable? It is the *human mind*—the most remarkable of all of the gifts with which man is endowed. It is this that makes man the one teleological animal—a far-thinking being. Man's horizon is extended far beyond the reach of "the senses," discussed in an earlier chapter. Not only does he reach out by "inference," but inference combined with invention enables him to see and hear what is going on at almost any given point in his vastly expanded environment. He can know what is happening in London or in Paris, in Peking or Melbourne. He can actually see and hear events far distant while they are taking place—practically as soon as the events occur. He can hear persons who are speaking thousands of miles distant; he can see things that are happening in the heavens millions of miles away; he can see things that are happening on the earth although long distances and great solid masses intervene. He knows the history, not only of the race as recorded by man, but also the history of all other living things. He knows the history of the earth as written in strata that date millions of years before the beginning of life; he knows how living things have changed, as told in terms of organic evolution. Almost every day he learns some important new thing about the past and stores his knowledge in libraries and museums as a part of that fund of information available to others for generations to come. The accumulated experiences and judgments of each are thus made available for his own future use and for the benefit of his fellows and of posterity. Knowing the past helps him better to understand the present. Most wonderful of all, knowing both the past and the present he works with greater precision and fuller knowledge when shaping the course for individual or group achievement. He thinks in terms of ideals—each comes to have dominant purpose.

**The Human Urge to Know.** Man, like other animals, is curious. Both have impulses to look, to hear, to touch, to taste,

to smell, and to respond in typical ways to other senses. But man alone has developed a marked capacity to reflect about his past experiences and to think new things while his organs of sense lie dormant, as it were. And so, being freed from the direct limitations of time, space and physical barriers, his imagination has fullest play. Some students of man believe that this habit of thinking about things which were not at the time sensed, was early called into service (in a more or less unconscious way, before man had learned to think in a scientific terminology) to explain the natural and social worlds in which men found themselves and to which they had to make adjustments. These explanations of nature and human nature may have manifested themselves as vague speculations—as reveries and dreams. They were communicated to others and became the common mental possessions of the group. Thus a vague sort of group thinking crystallized and took form as myths and other beliefs that had little obvious relation to ascertainable fact. These beliefs and fancies served to stimulate more scientific thinking. Gradually the mind of man came to be critical of older beliefs; and thus was started the search for new and dependable truths—the how and the why of occurrences, the sequence of past events, and the probabilities of events to come.

**Man as Seer.** For thousands of years, man sought to penetrate the veil of the future and to know what would be—before it actually happened. Perhaps all of us are alike in this respect, especially with reference to those things which most intimately concern ourselves and others in whom we are particularly interested. In earlier times, there were men who tried to look into the future by means of a certain mystical vision or by magic and divination. The gods were thought to have endowed the spiritual eyes of the seer with a power of vision not possessed by ordinary human beings. We now know that such magical endowment by the gods, of a few selected and favored men with an unusual power to see and know what other men could not see or know, was not possible, and that the only advantage which one man has over another in understanding his world is that which he learns through a deeper understanding of facts and their meaning, or science. He who would penetrate the meaning of

either the present or the future must pursue methods less romantic but more certain than divination. We have come to know from experience that in making forecasts, all our thinking must be based on a profound knowledge of nature and human nature as revealed through natural science, history, and the social sciences. It is through these three kinds of knowledge that man has come to be far-thinking—whether this thinking has reference to the future, to distant objects, or to past events.

**Animal and Human Minds.** So far, we have enlarged on what the mind does and how useful it is in making adjustments, without telling what it is. Broadly speaking, as the term is used in this and the chapter which follows, mind means the functional aspect of the nervous system, the highest controlling organ in which is the brain. The mind is the functioning of all mechanisms of response to stimuli that together constitute the organs of human and non-human intelligence.<sup>1</sup> We speak of the animal mind as distinguished from the human mind. As a matter of fact, there are all kinds of grades of development in the non-human mind, as well as in the human mind. There is no one type of mind characteristic of all animals below man or even of man himself. Because "mind" is here used as the functional aspect of the organized response mechanisms of intelligent beings, the kinds of mind possessed by both human and non-human beings are dependent upon the development of the animals' organisms and their nervous systems, and especially upon that most recent of all parts of their neural organization, the fore-brain or cerebral cortex. As was said in previous chapters, protozoans have no nervous system; and the lower metazoans have only relatively simple neural mechanisms, if any, to aid them in making adjustments to their environments. Even the higher mammals, including the anthropoids—the animals nearest man—have brains much inferior to man's brain. The human cerebral cortex, with its nine billion or more neurones, gives man a vast advantage over the other animals which have not such a highly developed cortical apparatus for use in association of ideas, reflec-

<sup>1</sup> *Editor's Note:* This is the behavioristic conception of mind. There are several other conceptions—each serving as a different approach to the scientific study of psychical phenomena. All agree, however, in the conclusion that there is a wide gulf which separates the human from the non-human mind, and that this is in some way related to the superior cortical equipment of man.

tion, and intelligent choice before action when making adjustments. It is through this cerebral cortex that all the more complex and rational adjustments of man to his environment—his far-thinking adjustments—have to be made.

**Different Conceptions of Mind.** Everybody who is intelligent knows that he has a mind; but it is not so easy for him to tell others just what part of himself functions when he thinks—and to set off this part as different or distinguishable from other parts or aspects of himself. The best way to define anything we cannot see and feel is, perhaps, to tell what it does. This is the way we have defined electricity, and magnetism, and gravitation, etc. This is the only way we can define life, and the mind. But that is not the way in which men have always defined the mind. They began with speculations and statements that were based upon hasty and premature observations and inferences, which could not meet the test of later experience. Out of the many definitions of mind based on early unverified speculations, we may select two types to illustrate our point.

**The Oldest Conception—That Mind is a Spirit.** The oldest view of mind is that it is a spirit—a sentient and thinking being, apart from the rest of man—something which inhabits his body for a time and directs its behavior, but is not a part of his body. In the old and cruder forms of this theory of mind, it was held that different spirits might inhabit the body at different times or even contend for its possession at the same time (as in the case of violently insane, epileptic, or hysterical persons). In this way they accounted for the marked changes of personality which were observed in persons under certain circumstances. Of course they did not like to have evil spirits dwell in their bodies; or if one acted in ways distressing to others, these other people did not like it. So not infrequently various methods were used in attempting to drive the evil spirits out of their bodies, sometimes by torturing them, by ducking (as in the case of so-called witches), or even, in extreme cases, by burning their bodies at the stake. It was thought that if an evil spirit or evil mind left the body, the good spirit would have peace; and if the body which had been “possessed” was freed of the “evil one,” a good spirit would have a chance to enter. When no spirit entered

the body for a considerable period of time the body was considered "dead," and the spirit as "departed." But death meant something very different to these early people from what it means to us, with our knowledge of organic chemistry, which they did not possess. They expected the spirit which rightfully owned the body to reoccupy it after some considerable period of time. Consequently they kept the dead bodies until they began to decay and then buried them with their possessions, supposing that their spirits would come and take them to another world, such as the Hades of the early Greeks or the "happy hunting grounds" of our American Indians. In other cases, as among the Egyptians, the bodies of important or wealthy persons were embalmed and sealed with their belongings in tombs, where they might be very comfortable until the spirits returned to occupy them. Comparatively few of the people we know today have this view of the mind and body, although it is still found among some of the more backward people of our isolated regions.

#### **The Dual Conception—Mind and Body as a Parallelism.**

Another view of mind developed by the philosophers shows some slight resemblance to this older view. In fact, it is but a much improved and less crude form of the earlier view from which it was derived. It is the theory known as *metaphysical parallelism*, or just *parallelism*. According to this theory, each personality consists of two kinds of substances or qualities. One of these is material, tangible, and physical; and it constitutes the body. The other substance is supposed to be immaterial and intangible; and this is the mental substance or quality, sometimes called the soul by theologians. This is in reality the old *spirit* with a new name. But in the modern form of this theory, the mind is supposed to be inseparable from the body, and develops as the body develops and disintegrates as the body disintegrates. The development and functioning of the one are supposed exactly to parallel the development and functioning of the other. Each, however, is supposed to have its own laws of growth and behavior. Another problem which troubled these earlier metaphysical psychologists was to discover how these two very different substances, mind and body, each with its own laws, were able to influence each other so closely as they apparently did. It was their inability

to answer this difficult question which finally caused the metaphysical psychologists, that is, the metaphysical parallelists, to lose their prestige with scientific people, and led to another definition of mind and another type of psychology to explain the working of the mind.

**The Behavioristic Theory of Mind—A Product of the Newer Psychology.** This new definition of mind is simply that it is the behavior of the organism, especially of the nervous system—and more particularly of the cerebral cortex—as it functions as a highly specialized organ of adjustment. The psychologists who use this definition of mind are called behaviorists. This view denies the existence of neither body nor mind, but unites both in the behavior of an organism reacting to stimuli. The thought of the modern psychologist is that one never sees evidence of the mind except when the body, and especially that part of it we call the nervous system and brain, are in action. It is, therefore, much more helpful to our thinking to picture mind simply as adjustment behavior—the way we act when we seem to have a purpose. It does not help us much to assume, as did primitive man, that we are guided by spirits which no scientist has ever been able to discover, even with the most delicate instruments of perception and measurement.

We may be more specific in stating our reasons for taking this view of mind. One challenging fact is that mental activity, as has been said, never occurs apart from the nervous system and the body. Another is that all protoplasm is, as we saw in preceding chapters, highly sensitive; and neural protoplasm is especially so. This sensitivity and retentiveness of protoplasm is apparently the basis of consciousness. When the cerebral cortex is highly active in selecting alternative urges to action (especially when it is holding the reflex and instinctive urges in abeyance) this sensitivity appears as consciousness, even as ideas and purpose in human beings. It is to be noted also that this consciousness always occurs normally in an adjustment situation. Even when one just thinks, without overt action, this thinking is normally in preparation for some future action; it is therefore a part of an adjustment situation, although it may not be an immediate one. Finally, we have learned to think of

the mind as acting even when we are not conscious or aware of what we are doing. We use the terms subconscious and unconscious mind or thinking when we try to explain how we make adjustments and choices of which we are not fully conscious or aware. Thus we automatically walk along the street or adjust the book we are reading without being aware that we do so. The same is true of our breathing, digestion, circulation, and of other vital functions, so long as they give us no trouble. This last type of unconscious behavior we ordinarily call instinctive, while the former type, consisting of those things we have learned to do, we call habitual behavior.<sup>2</sup>

### QUESTIONNAIRE WITH READING REFERENCES

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8. Which of these theories appears to you to be the best? Why?

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10. What are the advantages of using the words "brain" and "neuro-psyche mechanism" as symbols for ideas when dealing with the structural aspect, and the word "mind" when dealing with the functional aspect of instinct and intelligence?

See references cited above.

11. Does this involve a parallelistic interpretation or only two ways of looking at the facts of adjustment, i.e., objectively (in terms of mechanism) and subjectively (in terms of our consciousness of the adjustment)?

See references to Question 9.

12. In terms of neuro-psyche function, what is it that distinguishes man from other beings which have a neuro-psyche controlling mechanism?

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## CHAPTER XXIV

### MIND—ITS EMERGENCE AS A MECHANISM OF ADJUSTMENT

#### FAR-THINKING AND THE SUPERIORITY OF HUMAN ADJUSTMENTS \*

**Conscious and Unconscious Behavior.** The older psychologists were inclined to limit the terms mind and mental to those acts of which we are definitely aware. They spoke of other forms of behavior as physiological or physical behavior as distinguished from mental behavior. But the modern experimental psychologist is not able to find any definite dividing line between mental and physiological, conscious and unconscious, behavior. They overlap constantly. Physiological behavior frequently uses the neural mechanisms just as does conscious behavior, and all behavior, whether conscious or unconscious, uses physiological processes. Even the behavior of the neurones is apparently physiological. It is true that we ordinarily think of mind or mental behavior as the transmission of nervous impulses through neural stimulus-response mechanisms or processes. But this neural transmission of impulses is apparently a matter of physiology. Other physiological processes, such as the physiology of digestion, of circulation, of aeration, of excretion, and especially of the endocrines (particularly the thyroid, pituitary, and adrenal glands), also profoundly influence our mental processes.

**Popular Distinction Between Mind and Body Not Scientific.** In popular language we refer to our introspective or conscious experiences as mental and to those aspects of our behavior which we describe in terms of neurones, organs, muscles, secretions, etc., as neurological and physiological. Thus we have a popular habit of speaking of the "brain" and of the "mind" as separate facts. But the better view would seem to be that the

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\* By Professor Luther L. Bernard (see note at head of Chapter XXIII).

conscious experiences (which have been associated popularly with "mind"), and the neurological and physiological processes are only different aspects of the same thing. As was said before, we never see evidences of mind except when our organisms as units are making an adjustment or when our brains are sorting out impulses and ideas which may later be used in making such adjustments. Such adjustments, and thinking in preparation for adjustment, when we observe them in another person objectively, or even in ourselves introspectively, we call rational or irrational behavior, according as they do or do not occur in the way we commonly expect them to. Sometimes we say that a person who acts rationally, or as we expect him to act, has a good mind. Also we say that persons who act irrationally or unexpectedly appear to be "losing" their minds. It is also true that we perceive both our own and another's behavior, whether rational or irrational, only through our senses. There is no other way. We can know our world, including ourselves, only through the senses. Mind is, therefore, behavior functioning in adjustment which becomes conscious, if at all, through sensory perception.

**Possible Advantages of the Distinction.** There are some obvious advantages in making the popular distinction between body and mind referred to above, especially when we are describing our everyday experiences. It is often much easier to communicate our impulses-to-action to another by stating them in mental terms. Thus I may say, "I am convinced in my mind that I shouldn't eat any more, although my stomach is tempted." Or, "Our consciences rebel at gross bodily pleasures"; and "The flesh is weak," meaning that "we" (our moral and mental attitudes) must guard against our appetites. Again, I may say, "I have my mind made up." The average person understands these statements much better than if we stopped to say that the physiological chemistry of our organisms is out of harmony with our neural or brain organization, although this latter would be an equally true statement. That is because the mental responses or understanding of most people are much more effectively conditioned to the former words than to the latter—which is another way of saying that the one kind of language is more familiar to them than the other. But unquestionably, the latter method of

explanation is much more accurate and less figurative, and therefore more scientific, than the former. For ordinary purposes of communication we frequently like to use the less scientific terms, because they gain more from being brief and familiar than they lose on account of inexactness. Nor is such a term as "my mind is made up" necessarily inaccurate, if I mean by it that my whole organic attitude or set has become adjusted, as a unit, to the environment, and is ready to make a "drive" to achieve an end. In such a case it will be seen that "the mind" means more than just one's consciousness of the situation. It includes the attitude or preparation of the whole organism, not just the intellect or emotions.

**Man's Superior Brain.** We have spoken of the gulf which separates man from his non-human neighbors, due to his superior nervous equipment and his elaborate skill developed through his brain. No other animal approaches him with any degree of nearness in its ability to use its nervous system in consciously thinking out, or even in unconsciously selecting, new and better ways of adjusting to its environment. So slight is the ability of lower animals to use their nervous systems to make new adjustments that we commonly say that they cannot think. They act mainly on the basis of instinct, while man is primarily a habit-using animal. He makes new acquired adjustments when the old instinctive ones no longer work well. The other animals scarcely ever anticipate adjustments. Certainly they never think out new adjustments before the immediate need for them arises.

**Why Man Has Achieved This Superiority.** Only man is sufficiently far-thinking to plan his adjustments before they actually occur. The habits formed by lower animals are very slight modifications of their instincts, unless man himself directs their adaptation to new environments—that is, trains them. They cannot train themselves, because they lack the cortical or brain development which enables an animal to be far-thinking. Because the behavior of lower animals is so fixed and unadaptable to new situations, because it has so small a range, because it so frequently appears illogical to us when we observe it, and because the animal is apparently unable to picture to himself his own

behavior (that is, introspect it)—for these several reasons we say that the animal mind is very inferior to the human mind. By this we really mean that his behavior in adjusting to a changing environment is much less effective than man's behavior in adjusting to and in controlling such an environment. Because animals are so poorly equipped mentally and physically, they adjust themselves best to environments in which there is little change. But it is not alone man's exceptional brain that causes his behavior to be superior to that of other animals. Man has other advantages over the other animals, which will be explained in the following paragraphs.

**The Upright Position—Its Relation to Adaptation.** Man's upright position has also contributed much to his superiority. The upright position began to be achieved by the anthropoids, that is, by the apes and also by the monkeys. It aided mental behavior or thinking indirectly in two ways. The first result was to free the front limbs or arms and hands from the bothersome function of locomotion and enabled them to be employed in the more fruitful tasks of defense and food getting. Even such animals as the bear, squirrel, and kangaroo use their front limbs to a considerable extent for such purposes; but no other animal has front limbs so completely emancipated from service in locomotion as man. Freeing the hands from the task of locomotion meant freeing the mouth from the coarser tasks of food getting and fighting. Animals which seize their food by means of their mouths always have their lips, jaws, and teeth specialized for this purpose and not for purposes of word formation or speech, which is so important for man. The same is likewise true of those animals which fight with their mouths. A second indirect result of the upright position upon the adaptive behavior of the individual was that the hand became specialized for the purpose of manipulating the environment. With flexible and skilful hands man learned to transform his environment and thus to make it better suited to his needs and desires—he developed the arts.

**The Human Hand—The Most Wonderful of All Tools.** It is by means of his wonderful hands, unlike the prehensile organs of any other animal, that man has learned to see and hear and

talk all over the world and for the people of the future as well as to those of the present. Human hands, under the direction of the human mind, have produced those inventions by means of which man has become a far-seeing, a far-hearing, a far-speaking, as well as a far-thinking, animal. In fact, one cannot be far-thinking unless he is also far-seeing, far-speaking, and far-hearing. This power of manipulating and transforming the environment by means of his hands may be said to have shaped man's mind—it called for a more powerful brain with which to direct the highly specialized movements of the hands. Thus the development of the hands was one of the most powerful causes in the selection of a highly developed forebrain or cerebral cortex in man. This superior brain itself was necessary to enable man to direct his hands in developing the arts. And we have already seen that power of mind or effectiveness in the control of behavior is in the main dependent upon the degree of development of the cerebral cortex.

**Advantages of Freedom of Movement.** Other advantages, although not quite so great, depend upon the upright position. It gives the higher (exteroceptive) senses, which are always located in the head in the higher animals, a better chance to function effectively in adjusting man to his environment. Standing up, he can see farther and more readily in all directions than when on "all fours." He can also more readily make a defense or hunting adjustment to the source of any sound, without moving the whole of his body, as is necessary in the case of those animals which walk on all four feet. The upright position also makes it possible for man to move faster, either in escaping from danger or in pursuing objects of his desire. Because of his more rapid movement he has been able to specialize his body for peaceful pursuits rather than for those of fighting. Biologists have often commented on the fact that the human animal lacks most of those fighting devices, such as large jaws, heavy horns, and long claws, which weigh down or impede many of the lower fighting animals. The upright position, the highly specialized hands, and the superior brain, which mark man off from other animals, have enabled him to dispense with those more primitive and burdensome devices for making adjustments to his environment.

**Human Language—A System of Word Symbols.** Added to these three powerful adjustment devices of man is a fourth one equally powerful and helpful. It is the highly specialized vocal apparatus which helps to render him unique among animals. Other animals make cries and some scientists think they possess the rudiments of language. But only man uses words. This is because, in addition to vocal cords which other animals also possess, the human species has developed in its type of organism the kinds of mouth and chin, lips and tongue, which are capable of shaping words out of the vowel tones and other sounds which arise from the passage of air over the vocal cords and through the mouth. Language is one of the most wonderful of all the gifts or powers of man. By means of it he is able to communicate his wishes to others and to obtain from them cooperation in his undertakings. Man has become a cooperating animal in the degree to which he has become a language using animal. His intelligence has grown equally with his development of language.

**Vocal and Written Human Language.** From all the evidence at hand it appears that verbal language was not the first type of language which man developed. Vocal language was by far the best means of communication before written language was invented. The earliest language was a sort of instinctive one of the emotions, consisting of the emotional expressions of the face and body and the emotional cries indicating fear, hunger, anger, etc.

Such emotional expression, possessed by man in common with the lower animals, has been described in much detail by the great naturalist, Charles Darwin. The anthropoids also possess the rudiments of communication by gesture, which is in reality among them a phase of emotional expression. With the freeing of his hands from the task of locomotion, man was able greatly to extend his use of gesture language. But, of course, gestures are useful primarily as rough indicators of meaning. Primitive man did not know how to make words out of gestures; hence his communication by gesture was emotional rather than intellectual. It has remained for modern man to invent gesture languages based on words, such as the deaf and dumb

languages of our day. Thus, verbal gesture language was invented after verbal vocal language, which was the first really intellectual language in the world. It was the development of the human mouth and human brain which made it possible for the old animal cries to be broken up into words. Now, words name things and indicate behavior with reference to them much more clearly than gestures ever could do. This fact makes it possible to distinguish meanings very clearly by means of words and to convey them accurately to others. That is why we say that verbal language is intellectual language, as distinguished from the emotional language of animal cries, gestures, etc. But the most intellectual form of verbal language is not vocal, but written language. This is the latest type of language to be developed by man as an aid in making more effective adjustment to his environment.

**Verbal Language and Cooperative Adjustment.** We said that one great function of verbal language is to help man to make cooperative adjustments with other men to their common environments. Thus, verbal language is particularly responsible for the growth of human groups or collective life. It is verbal language which makes man the most highly socialized of all animals—if we include progressive or intelligent adaptability as one of the necessary characteristics of socialization. Some of the insects appear to be even better adjusted to their static social organization. But apparently they have no power to make new adjustments. It is in thinking, or in his capacity for adaptation to the new, that man is so radically distinguished from all other animals, including the ants and bees. Verbal language has perhaps proved to be the greatest of all stimuli to thinking and mental adaptation—greater even than the specialization of the hands. The use of verbal language greatly increased the number of adjustments which had to be made by man, because it complicated his relationships to his environment, including other men. This taxed his inner adjusting mechanism, the cerebral cortex, to its limit and doubtless forced in the species the selection of higher types of neural mechanisms. Those who proved the more “fit” to survive in a world with verbal language were obviously individuals equipped with a more powerful forebrain. They proved more “fit” not only because the use of the hands and language transformed and

complicated the environment and made necessary a better brain to guide the hands and speech; but they also proved more capable of cooperation. Thus, the growth of inventive hands and an intellectual language has reacted back upon the brain, causing a more powerful brain to be selected in order to handle effectively the vastly increased forms of adjustment to environment. In this way the capacity and the far-thinking powers of the mind have been greatly increased in man until in these respects, as well as in his physical structure, an impassable gulf has been created between him and his non-human neighbors.

**Man's Powers of Analysis.** The width of this gulf may be illustrated in a number of ways. The difference in the powers of man and the lower animals to analyze an objective situation is an instance. A horse or a dog may form fairly clear perceptions of the objects with which he frequently comes in contact. Thus, the dog sees and recognizes his master, his bed, objects of food, a rabbit, etc. But the meaning which such objects have for him is much more limited than that which they have for a man. The man relates them to many more objects in his environment. To the dog the rabbit is a moving object to be chased and eaten. To the man it is that, but it is also a menace to fruit trees and gardens, a prolific breeder, an animal of a certain species with peculiar markings and habits of adjustment to its environment, etc., etc. In the language of psychology we say that the stimulus (rabbit) conditions vastly more experiences and responses, or arouses more associations, in the man than in the dog. The dog "sees," in a vague sort of way, most of the more obtrusive objects about him, but the man "sees through" them. That is, they have a much richer meaning for him because he is capable of analyzing their relationships to one another and to other more distant objects, as well as to himself. This greater power in the man is partly due to his superior brain and partly to his power of naming things. Being possessed of language symbols he can label such objects with words and objectivate them. Objectivating objects by naming them means to think about them instead of to react to them emotionally. The lower animals, which are without verbal language, react almost wholly emotionally to objects; while highly cultivated men, with a very good command of scientific

language or terminology, react or behave intellectually more often than emotionally towards objects in their environment to which they must adjust themselves.

**Man's Powers to Make Things.** Another distinction between man and the lower animals lies in the difference in their ability to make things. As we saw above, the wonderful brain of man and his remarkable hands working together upon the environment have been able to transform nature to a considerable degree into man-made conveniences and aids to his adjustment. Man is distinctively an inventive animal. He not only makes things with his hands working under the guidance of his brain, such as agricultural tools, weapons, ornaments, machines, etc., but he also makes more complicated things with which to make other things. These are really extensions of his hands which he uses to make things more quickly or effectively or accurately than he could make them with his bare hands. In their simplest form these extensions of his hands are tools, but in their more complex form they are machines. The machines are not only extensions of his hands and of his muscles; but usually also, especially in our industrial age, they are adapted to the absorption and utilization of power drawn from sources other than human or animal muscles with which to do their work. These machines frequently work much more uniformly and much more accurately than the average hand, and they not infrequently utilize power equivalent to hundreds or thousands of human hands.

**Man's Ability to Shape and Use "Tools."** Also, man has learned to make physical extensions of his senses which enable him to see and hear things much better than he is able without such instruments. The microscope, telescope, telegraph, telephone, phonograph, and radio have given man's senses a range and penetration of which no one ever dreamed before the nineteenth century. Only human hands and brains, and man-made tools and machines, could ever have made such inventions as these. The greatest of all human inventions perhaps are those by which he improves his powers of thinking. By means of these inventions man uses his mind to make its working even more effective. These inventions are language, systems of logic (including mathematics),

and such physical inventions as calculating machines, census tabulating machines, seismographs, meteorological instruments, etc. The lower animals never make any but the simplest empirical inventions and these only by accident. They never produce tools or machines with which to make other tools or machines. And they are so little able to produce any invention or mechanism with which to improve either their own or man's thinking powers, that they are not even capable of responding intelligently to those produced by man. Aside from a limited response to the human language mechanism, the lower animals show no understanding of man's thought-aiding or far-thinking inventions. In fact, this is almost equally true of all of the rest of the human inventions and instruments of human adjustment to environment.

**The Practical and Fine Arts.** It follows from what we have said that no other animal besides man has developed the arts. This is true of both the applied arts and the fine arts. Both are based upon the power to make inventions, which is practically non-existent among the animals. The fine arts are also dependent upon the possession of some power of aesthetic analysis and synthesis, which is a form of abstract or conceptual thinking. There is no reason to believe that any non-human animal has such powers in sufficient degree to produce a work of art, even of the simplest sort. The beautiful and highly effective products of the skill of some of the lower animals, such as the elaborate nests of birds, the cells of bees and wasps, and the dams and huts of beavers, are apparently the product of instinct or of relatively simple conditioned responses, rather than of purposive thinking. No animal has ever fashioned a tool, painted a picture, or made a piece of statuary. Nor has any animal ever developed a trade or profession, although some animals are good, but not intelligent, workers. Both types of arts, as we use the term with respect to human achievement, involve a considerable power of thinking and reasoning, and in their higher forms they are dependent upon a large development of science. Animals are neither artists nor artisans, just as they are not capable of becoming inventors and thinkers.

**Science and Human Progress.** Man is the only animal that has ever been able to develop, and live in, an age of science. The domesticated animals also share some of the advantages, as well

as many disadvantages, of the human age of science. But their participation in the scientific age of man is indirect and comes through the training and care, or exploitation, which man exercises over them. This age of science came very late in the history of the world. The geologists and astronomers tell us that the earth is a billion or more years old. Many anthropologists and archeologists think that man has existed on the earth something like a million years. But the age of science is less than three thousand years old, and in many very important senses it has existed for only about two or three hundred years. It came into existence only when man invented and learned to use a highly abstract or quantitative language, represented especially by mathematics, and a qualitative language of logic, by means of which he was able to distinguish clearly and measure the attributes or characteristics of objects. A highly perfected language, with which to name, and measure things, made possible the age of science. Science stimulated inventions and inventions in turn stimulated the arts.

#### **Development of the Human Mind a Matter of Training.**

But the order of development was not wholly in this one direction. The arts constantly call for more and more effective inventions, and invention demands ever greater developments in science as an aid to further invention. Thus, each of these several forms of adjustment behavior or of far-thinking stimulates the other, once all of them have been initiated. According to our definitions of mind and of thinking, language, science, invention, and the arts are all forms of adjustment-seeking behavior in a changing environment. Hence, they are methods of far-thinking. It is by means of them that man secures a better adjustment to his changing world than would be possible without them. It is because he possesses the power to develop and utilize such aids to effective adjustment to his changing environment that he is so far removed from the lower animals which do not possess such powers and skills.

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## CHAPTER XXV

### MIND—ITS EMERGENCE AS A MECHANISM OF ADJUSTMENT

#### PROGRESSIVE COMPLEXITY OF ADAPTIVE MECHANISMS \*

**Types of Human Behavior.** In the human infant (as in the animal world below man) behavior takes these forms: random movements; reflexes; instincts (relatively few); and as many habits as the organism has been able to acquire. *Random movements* are seemingly non-purposive and very imperfectly coordinated motor activities, such as the arm and leg movements of a young child. They are in part the result of a high rate of metabolism—surplus energy produced by physico-chemical changes incident to the cell life within the organism—but for the most part these movements are initiated by stimuli received from without. Movements commonly called *reflexes* are relatively perfect in their coordination; they are characterized as preconditioned responses of organs to stimuli; in simplest form they are the actions which take place automatically as unlearned responses of the inborn mechanisms. Familiar examples of reflexes are the winking of the eye in response to light or the dryness of the eyeball and sneezing when a foreign body has entered the nostril. *Instincts*, most psychologists and neurologists now agree, are merely more complex inherited responses to stimuli, such as chains or complexes of the simpler reflexes. Familiar examples of instinctive responses are the mechanisms of breathing, circulation, digestion, some of those connected with reproduction, the automatic response known as swallowing, etc. There is no difference between “reflexes” and “instincts” except that added complexity incident to coordination of reflexes and their integration in larger units of behavior.

*Habits* are acquired responses and may become as automatic as

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\* By Professor Luther L. Bernard (see note at head of Chapter XXIII).

reflexes and instincts as a result of practice. They are learned responses and are modified by experience, although they are based upon the original or instinctive stimulus-response processes and random movements.

A *tropism* is any sort of relatively unvarying response of the whole organism to a characteristic effective stimulus, in which the response is determined by the physiological or anatomical constitution of the organism. Thus the moth flies toward the flame because the light stimulates its activity physiologically and its bilateral and bifocal symmetry causes it to fly in a straight line towards the object which stimulates it to fly. In making a tropic response the animal uses whatever reflexes, instincts, or habits it possesses. Thus, tropisms are more general than reflexes, instincts, and even than some habits and may include them. Any relatively constant form of behavior, whether inherited or acquired, may be thought of as *behavior pattern*, or *mechanism*. Some behavior patterns are as simple as reflexes, while at the other extreme they may be as complex as a ritual.

**Why Animals Have Habits.** The behavior of the lower animals is controlled primarily by inherited reflexes, either those which are relatively simple (called simple reflexes) or those which are relatively complex (including the instincts). Simple habits are in the nature of reflexes acquired after birth. Those habits serving as aids to the adjustment of the lower animals are usually simpler than most of those developed by man; they are also fewer in number. Man, especially after early infancy, develops a great many habits. Because of his greater neural flexibility, he is the chief habit-forming animal. This is because he lives in a much more complex environment than the other animals and his environment changes so much more rapidly than theirs that instincts and reflexes will not suffice to take care of his adjustment behavior. Non-human beings adjust their organisms only to relatively stable environmental conditions. If any animal which has a nervous system is compelled to adjust itself to changed conditions it must modify its inherited behavior patterns. Repetition of learned adaptations according to new patterns fixes the new behavior and a new or second nature is acquired. Responses accord-

ing to these new patterns are habits. The reason for the habit is to be found in the better adjustment gained thereby.

**Man Peculiarly a Habit-Forming Animal.** The lower animals, such as the insects, live for but a short period, usually a season or less; they live in a relatively uniform medium, such as earth or water, and do not migrate to any considerable distance. Consequently, they are not subjected to any marked changes in temperature, humidity, or food conditions. Their environments are extremely simple as compared with those of man and other higher animals. Animals with longer life periods and with greater powers of locomotion are subjected to varying temperatures, humidity, and food conditions. These animals, consequently, must change their behavior to suit their new circumstances. It is for this reason that they form habits. Man is especially active in changing his environments by changing his place of residence, in subjecting himself to all sorts of temperature and humidity conditions, and to new food environments. In addition to these modifications of his relationship to environment, he also creates for himself new social environments which are even more complex than the old social environments. The result is that he must modify his behavior patterns frequently and markedly. This is why he is the chief habit-forming animal. Because he has lived so long in a human world where others take care of him in his infancy, so that he does not have to shift for himself almost as soon as he is born, he does not have some of the instincts common to other species. He cannot walk or secure his own food until many months after he is born. Man is born with fewer instincts and he acquires many times more habits than other animals.

**Two Kinds of Habits.** The habits which animals of different grades of development acquire differ in kind and in complexity. Thus, the lower animals develop overt or neuro-muscular habits on the trial and error basis. But man, with his highly organized cerebral cortex, is able to form internal or verbal (neuro-psychic) habits without the complete overt or neuro-muscular responses. Thus we say that the animals below man act out the new adjustments, often wastefully as respects time and energy, without thinking. Their trial and error responses are neuro-muscular or

overt. But man often thinks out an adjustment before he acts it out. His trial and error responses are internal or neuro-psychic, and these often find expression in words. He often makes a new overt adjustment response only after he has thought out and talked over how he should act. In this way man may save much time and energy lost by the lower animals in useless movements. Thus, when for the first time a man opens a gate, he "figures out" the mechanism of the lock or latch before he attempts it. But the horse does not "figure out" how to open the gate before trying it. He makes many attempts until possibly, by good luck, he hits upon the right method. His trial and error method is overt or neuro-muscular, while that of man is internal or neuro-psychic. The horse does not think at all in the sense of internal or verbal behavior. He uses the method of overt or neuro-muscular habit adjustment, while the man makes use of internal neuro-psychic and verbal habit in making his adjustments. Both use neural mechanisms, but in the one case the response is immediate and overt; in the other case the overt response is delayed and the immediate response is internal or neural and psychic.

**Language as a Form of Habit.** As stated in the previous chapter, man is unique in his capacity to communicate by use of verbal language; while the lower animals have only a very rudimentary use of non-verbal language. The language of the lower animals is largely instinctive and serves to communicate only the simplest attitudes and desires or wants, and even these probably without any consciousness of purpose. Animals are usually able to communicate attitudes of fear, anger, food and sex desire, and possibly a few other simple impulses. But man's language, while including such simple quasi-instinctive signals as the above, is much more complex and is mainly acquired. Much of his emotional expression, most or all of his gestures, and all of his verbal language symbols are acquired. So language forms another great field of habits or acquired behavior patterns. Language is a form of overt behavior and is directly perceptible to another person to whom it has meaning. But it also has meaning to the person whose language it is. This is his consciousness of his attitude and corresponds to his language, which expresses this attitude to another. The only way in which one person can

apprehend or respond to the internal or neuro-psychic content of another's behavior, that is, to what he thinks, is by responding to the symbols which we call language.

**Language Symbols.** Language symbols, whether primitive emotional expressions, gestures, or words, are either the partial and incomplete or the substitute responses which are made by an animal when it inhibits a trial and error or other overt response and transfers the adjustment to the inner or neuro-psychic responses, there to be thought out or prepared before the overt or neuro-muscular adjustment response is permitted to occur. Thus, language arises in emotional or in thinking adjustment situations, and the language is either emotional or intellectual to correspond. Verbal language especially is intellectual, because it is the highly symbolical language by which we name things or objects. This naming of things enables us the more readily to compare them, and comparison is an intellectual process. It helps us to select our adjustment behavior.

**The Forms of Language.** Those forms of language known as primitive (emotional expression and gesture) are nearly always partial or incomplete overt responses which occur as overflow movements when the complete overt response is inhibited. They are simply surviving parts of the total response which was incompletely suppressed. Thus, the clenching of the fist is the preliminary part of a blow, which it symbolizes as a gesture. The raising of the hand, palm outwards, is another gesture or partial and incomplete overt act, symbolizing the complete act of pushing away a disagreeable object. Darwin said that the showing of the teeth by animals is the partial survival of the total overt act of tearing the flesh of an antagonist.

Vocal language, on the contrary, is largely in the nature of substitute expression. Words and cries are overflow expressions when the ordinary outlet through overt bodily response is inhibited or insufficient. Thus we talk when we cannot act overtly, or do not consider it best to do so. Out of this type of substitute response, speech, the most important type of language, has been created. Written language is merely the translation of vocal symbols, with certain advantages for communication of ideas and attitudes which we shall explain later.

**Language as Means to Adjustment.** The point to note especially in this connection is that language, of whatever type, is also a form of habit and has been developed as an aid to man in making his adjustments to environment. It is in some respects a higher form of habit than the other types which we have discussed, because it is used primarily in making adjustments to the human environment, while the other forms of habit are employed in making adjustments to the non-human environments as well.

We may indicate the stages of the development of habit modifications of instinct by means of the diagram shown on page 439. This diagram may be used to illustrate the steps by which man has ascended from the animal to the human status and to civilization. The diagram fails to illustrate adequately only one fact, viz., that the various stages of adjustment here indicated as steps are not separate and distinct. Each stage or step grows out of the one preceding it, and all of the preceding types of behavior continue to aid in adjustment after the new type appears. Mental habit or inner trial and error (neuro-psychic) behavior grows up with language or symbolic behavior. The one is the inner and the other the outer aspect of the same advanced adjustment process. The inner or neuro-psychic form of habit or trial and error begins first with gesture language. Vocal and written language are merely more advanced stages of the same adjustment process.

**Thinking as a Form of Habit.** From this account we see that thinking is a form of habit—primarily an internal or neuro-psychic habit. Thinking is also closely related to, or dependent upon, language habits. People who have not a good command of language habits are not good thinkers. They are not able to describe things well or to express themselves intelligently, we say. Such people may be better at doing things quickly and forcefully than they are at thinking things out in order that they may do them well. The motor type of people often make good leaders where much action is needed, because their example and earnestness are contagious. But they rarely or never make effective leaders where the education of others with respect to the program is a part of the task of leadership. Thinking is a response to suspended action—a form of suspended adjustment

DIAGRAM SHOWING PROGRESSIVE COMPLEXITY IN THE ADAPTIVE MECHANISMS  
OF LIVING THINGS FROM PLANTS TO CIVILIZED MAN

Adjustment through Primitive Tropisms	THE ADAPTIVE MECHANISMS OF PLANTS AND OF THE VERY LOWEST ANIMAL FORMS—in which there is no nervous system, and consequently no nervous habituation.					
	Adjustment through Instinct	THE ADAPTIVE MECHANISMS OF LOW ORDERS OF ANIMALS—which have a relatively simple nervous system and therefore a low order of overt habits based on neural adaptation and no mental habituation.				
Adjustment through Primitive Tropisms	Adjustment through Instinct	Adjustment through Overt Trial and Error	THE ADAPTIVE MECHANISMS OF THE LOWER VERTEBRATES—highly developed instinctive mechanisms, but with little or no mechanism for association of ideas and thinking.			
Adjustment through Primitive Tropisms	Adjustment through Instinct	Adjustment through Overt Trial and Error	Adjustment through Lower Order of Inner Trial and Error	THE ADAPTIVE MECHANISMS OF THE HIGHER VERTEBRATES—with a less highly developed instinctive equipment in many respects, but with more highly developed brains.		
Adjustment through Primitive Tropisms	Adjustment through Instinct	Adjustment through Overt Trial and Error	Adjustment through Lower Order of Inner Trial and Error	Adjustment through Vocal Language Mechanisms	THE ADAPTIVE MECHANISMS OF PRIMITIVE MAN—with highly developed inherited equipment both for overt response and for thinking, but with inferior environments for mental habituation.	
Adjustment through Primitive Tropisms	Adjustment through Instinct	Adjustment through Overt Trial and Error	Adjustment through Lower Order of Inner Trial and Error	Adjustment through Vocal Language Mechanisms	Adjustment through Written Language Mechanisms	
Adjustment through Primitive Tropisms	Adjustment through Instinct	Adjustment through Overt Trial and Error	Adjustment through Lower Order of Inner Trial and Error	Adjustment through Vocal Language Mechanisms	THE ADAPTIVE MECHANISMS OF CIVILIZED MAN—with inferior instinctive equipment and superior brain mechanisms, surrounded by superior environments for the conditioning of mental habituation.	

N. B. Read to the right and upward.

response to an environmental problem. The thinker waits until he foresees the ultimate results of alternatives; he compares verbally several possibilities of behavior before he decides; then he attempts to make an overt adjustment.

**Classes of Factors That Inhibit Pattern Responses.** There are two classes of factors which suspend overt adjustment responses and result in thinking as a method of delayed response. These are external or environmental factors, and internal or neuro-psychic factors. We shall consider the second type here. In the higher animals, most particularly in man, a large number of acquired inner or neural behavior patterns accumulate, and these often inhibit or suspend the impulse to do some particular thing for which there has been a stimulus ordinarily effective. We say that lower animals lack these neuro-psychic inhibitions to their impulses. By this we mean that their mental habits or neuro-psychic processes are not sufficiently well developed and varied to interfere with any instinctive or previously acquired impulses which motivate them. Only thinking animals, that is, men with some degree of cultural development, are able to delay and control their overt responses by means of their inner behavior patterns.

**Environment Selects or Determines Inner Habits.** These inner or stored habit patterns are, however, accumulated in the highly flexible human cortex, because of the selective operation of external or environmental stimuli. Hence, environment is the original inhibitor of impulses and creates the internal or acquired inhibiting patterns. In the lower animals, environment is able to inhibit the overt response only after it is in the main completed. This is what occurs in trial and error learning, where the completion of one erroneous overt response sets in operation a stimulus to another response, with the result that the process goes on until the animal becomes fatigued and ceases trying or succeeds by accident in making the response which gives him what he wants. Even the lower animal acquires inner or neural adjustment mechanisms as a result of successful adjustments which will later inhibit the erroneous overt responses when the same stimuli are operative.

**The Beginning of Learning.** The child starts out in the same way as the animal, learning by trial and error. But because he has a much better brain he learns more quickly and soon has a large store of acquired inner adjustment patterns or mechanisms which inhibit erroneous overt responses. But most important of all, because the human being possesses verbal or intellectual language, he is able to take over the experience of others vicariously without himself having gone through all of their overt trial and error experiences. Thus, the human child acquires through conversation and reading vast amounts of inner habit patterns or mental content which serve to inhibit erroneous overt responses. In this way environment has built up or conditioned a large number of inner acquired habit patterns which are assimilated through language mechanisms by all of the intelligent or cultivated members of the human race. And thus the content and mechanisms for our thinking are acquired as habits as the result of cultural or environmental pressures. It is in this sense that mind is primarily a human or cultural product.

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## CHAPTER XXVI

### MIND—ITS EMERGENCE AS A MECHANISM OF ADJUSTMENT

#### RELATION OF ENVIRONMENT TO MENTAL DEVELOPMENT \*

**Types of Environments.** If we are to understand adequately how man became possessed of the powerful acquired instrument described in a previous chapter—his mechanism of intelligent adjustment—it will be necessary for us to understand more about the nature of his environments and the ways in which they operate upon him to produce his mental responses. We have already pointed out that man has much more complicated environments than other animals. Both have the environment of nature, which may be thought of as inorganic and organic. Man comes in contact with nature, directly or indirectly, in all parts of the world, while other species are limited to more favoring zones. This difference in ubiquity between man and other species is due to the fact that the non-human types have not been able to create social environments by means of which they can modify favorably their adjustments to nature. But man has created or evolved very extensive social environments and with these he softens the rigors of the natural environments. Consequently, the several kinds of environments described below are much more important directly for his development than the natural environments. Keeping before us these broad distinctions, the several environments of man may be outlined as follows:

I. THE NATURAL ENVIRONMENTS, or the untransformed aspects of nature:

1. *The inorganic environment*—consisting of cosmic materials and processes, physical geography, soil, climate, the inorganic resources, natural agencies, and natural mechanical processes.

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\* By Professor Luther L. Bernard (see note at head of Chapter XXIII).

2. *The organic environment*—consisting of micro-organisms, various parasites and insect pests, plants, animals, ecological and symbiotic relationships of plants and animals, the prenatal environment of man, and natural biological processes.

II. THE SOCIAL ENVIRONMENTS OF THE FIRST ORDER, or those physical transformations of nature which enable the organism to adjust itself more effectively and economically, although more indirectly, to the natural environments :

1. *The physico-social environment*—consisting of physical inventions, illustrated by tools, machines, houses, shelter, means of transportation and communication, cities, artificial ice, fire, clothing, instruments for scientific research, etc.

2. *The bio-social environment*—consisting of the natural organic environment as modified by training, and by plant and animal breeding. Examples of this form of the social environment are domesticated plants and animals, pets, slaves, trained servants, and laborers, artisans, athletes, students, soldiers, etc.

III. THE SOCIAL ENVIRONMENTS OF THE SECOND ORDER, or the psycho-social environments, based upon language symbols and communication :

1. *The psycho-social environment*, dependent upon *gesture language*. The content of this phase of the psycho-social environment is relatively meager. It begins in the lowest stages of savagery, but persists into the present.

2. *The psycho-social environment*, dependent upon *vocal language*. The experiences of men are symbolized verbally and communicated from one person to another until they become common possessions, by the method explained earlier in these chapters. These common or collective experiences are made objective through language and they take on the forms of traditions, customs, folkways, conventions, beliefs, mores, proverbs, maxims, public opinion, etc., etc. They are discussed in Chapter XXVII as part of objective culture. As such they constitute a large and increasing phase of the social environment, and it is from them that we obtain most of those behavior patterns which guide us, especially in our more formative years. This aspect of the

psycho-social environment is relatively most important before the advent of written language.

3. The third aspect of the *psycho-social environment* to develop appeared with the introduction of *written language*. The vocal forms of the psycho-social environment continue to function broadly along with the written forms and probably outnumber the latter. But written or printed matter has several advantages over the oral content of the psycho-social environment. It is relatively permanent, does not easily lose its identity in transmission, is easily verifiable, it can carry a heavier content of serious intellectual matter and can carry it farther from its origin without distortion or depletion. From the standpoint of accuracy and distance of communication it is decidedly superior to the vocal aspect of the psycho-social environment. But, of course, it lacks the vividness and emotional suggestiveness of the latter. The written content is carried through books, newspapers, phonograph records, movie films, and pictures. It takes the form chiefly of poetry, drama, fiction, art, essays, history, laws, codes, philosophy, and the sciences. The sciences especially could not exist except for this written or printed medium, and they are the basis of our modern civilization. Without the sciences, both theoretical and applied, we could not have our industry, medicine, sanitation, hygiene, political institutions, and the other highly developed forms of social organization and control. This last phase of the psycho-social environment brings us to a consideration of the last great type of social environment, that of the third order.

IV. THE DERIVATIVE-CONTROL AND INSTITUTIONAL ENVIRONMENTS. These are composite environments, made up of all forms and varying degrees of organization. But they are dominated particularly by the psycho-social environments. Except for the bio-social and physico-social environmental elements in them, they might properly be regarded as more highly organized and more objective aspects of the psycho-social environments. They consist of both institutional and non-institutional forms, but the institutional forms are the more important, because they are more stable and permanent. In either case they consist of the psycho-social elements of tradition, belief, con-

vention, law, code, etc., with physico-social and bio-social organizations and equipment developed for the purpose of carrying out the aims and purposes set by the psycho-social environments. These bio-social organizations are distinguished by MacIver as "associations." Thus, the state as a political association has its bio-social aspect and has its psycho-social elements of laws, codes, traditions, customs, etc., which dominate the government and those who are governed. But it also has its physico-social equipment, such as buildings, ships, roads, and the like; these are made effective as "tools" by organization of such bio-social adjuncts as citizens, trained soldiers, government clerks, school teachers, domesticated animals, etc. All of these go to make up derivative-control environments and together, in their organized form, they constitute institutions and associations—the first as patterns, the second as organs of cooperative achievement. The reader knows many other institutional and non-institutional patterns for group action, and bio-social forms of organizations, which illustrate equally well the nature of the derivative-control social environments.

### **Importance of Cultural and Institutional Types for Man.**

These last two general types of social environments are especially important for man because they determine in the main his behavior through mental means or controls. What each individual thinks and believes about all of his relationships in life is determined by these environments. For example, the religious institutions determine our religious views; the political and educational institutions, what we think about government; the economic institutions, what we believe about the proper types and functions of industry. Or it may be that our views in any one of these fields are influenced by other institutions, as when our industrial relations help to determine our political or religious views. Traditions, conventions, the group mores, the laws, and the sciences taught in our schools also influence strongly our beliefs and actions. Although man built up the psycho-social environments through the gradual accumulation of deposits from his thinking and acting, these environments also in turn determine in the main what the thinking and acting of succeeding generations will be. The natural environments control almost wholly the be-

havior of the lower animals, and this was also largely true of early man. But modern man has gone further; he has built up physico-social, bio-social, psycho-social, and even derivative-con-

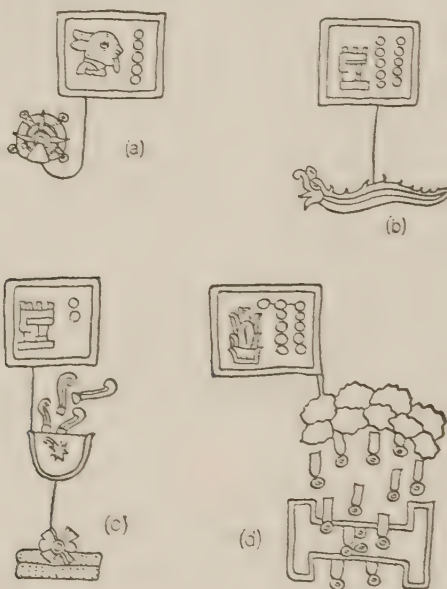


Figure 115. Primitive Language Forms—Natural Phenomena Recorded in Aztec Hieroglyphics.

(a) An eclipse of the sun which took place in the year 5 Rabbit (1510 A.D.). The year is represented by the rabbit's head and the five dots in the square above, and the eclipse of the sun by the picture of the sun's disk with a sector bitten out of it.

(b) A comet which swept over the Valley of Mexico in the year 10 House (1489 A.D.). The year is represented in the square above and the comet by the serpent below.

(c) A volcanic eruption and earthquake in the year 2 House (1533 A.D.). The year appears in the square above. Below is a star with smoke curls rising above it, the sign for a volcanic eruption, the Aztec word for which is "smoke ascending to the stars." Below is the sign for an earthquake, a sort of winged eye, meaning "movement" (Aztec *ollin*), applied to the earth, the speckled rectangle.

(d) A heavy fall of snow which occurred in the province of Tlachquiacho in the year 11 Reed (1503 A.D.). The year appears above. The bank of clouds indicates the snow, and the H-shaped object below, covered with water symbols, is the hieroglyphic for the province of Tlachquiacho. (Courtesy of the *National Geographic Magazine*.)

trol environments, which take the form of composite social environments, of inventions, better bred and trained persons and animals, traditions, conventions, and knowledge. As a matter

of social organization these take the form of complex control "institutions" and specialized functioning "associations." Thus man has been able largely to free himself from the direct and crude control of his natural environments and, in turn, to control them in great measure. The social environments serve as mechanical, organic, and mental buffers between himself and inexorable nature.

**Language and the Social Environments.** These highly elaborated new social environments are not only the product of the superior organic structure and intelligence of man; they have reacted in turn upon his inherited equipment so that this becomes markedly changed after birth; they have modified human relations to create even higher types of social organization and greater degrees of natural ability and intelligence. These results have come about by a process of selection and differentiation of organic types and by training these for more effective behavior. As we saw above, language has latterly played the larger rôle here. It was through language—spoken and written—that man was able to objectivate his behavior and create his psycho-social environments; and it was also by means of language that he was able to organize his derivative-control or composite social environments. These environments react back upon man and remould or recondition his behavior primarily through the mechanism of language. The content of our literature, science, law, and culture in general, is able to take effect in moulding our behavior and to influence our thinking almost exclusively through language—that is, through words and combinations of words. Literature and science are, in reality, but words and combinations of words, which symbolize behavior (both neuro-psychic and overt) in us and are therefore able to act upon us as stimuli and cause us to think and act in our adjustment situations in certain ways.

**Inventions as Social Environments.** Inventions belong to the social environments made by man. The accidental and simple empirical inventions of man correspond to his adjustments to his environments—especially to the natural environments—primarily on the basis of overt habit responses. But in making the projective inventions of modern times, in which the inventions are very complex and are thought out beforehand in great detail

and then completed in material form or in collective behavior, internal or verbal (mental) habit is used. In the projective invention internal or verbal habit is used exclusively in thinking out the details of the invention, for such an invention is a true delayed response. We defer a final adjustment until we think out an invention with which to make the final adjustment. But when the final adjustment comes, it is usually in the form of an overt response or a series or group of overt responses. Both the empirical and the projected invention may be either physical (as in the making of a club or a locomotive), or social (as in the origin of leadership or in the making of a modern constitution). But the projected invention of either type (physical or social) is made first in words. Thus, we construct the locomotive in the form of mathematical and other language specifications before we make it of steel. The constitution is an organization of words. Consequently, we see that the making of inventions, which constitute the chief content of the social environments, is primarily a process of making language forms and organizations or of putting projected or future behavior into language. The sciences, by means of which we make the complex or projected inventions, are themselves but organizations of language forms which symbolize our thoughts and have the power as stimuli to call up in our minds thought responses.

**Mind—A Complex Integration of Acquired Behavior Patterns.** The mind is a complex organization of acquired behavior patterns used in adjusting ourselves to environmental situations. These behavior adjustment patterns which are the content of our minds are mainly inner or verbal habit mechanisms or neuro-psychic processes. Like the objective physical and social inventions which are projected by these inner or neuro-psychic mechanisms of language, they are being constantly created or invented, or acquired, as the result of the reaction of environment upon us. That is, we invent new thoughts or ideas, just as we invent new environments consisting of machines and schools or governments. The latter are nothing more than the visible or objective forms of our thoughts anyway, and both grow up, or are invented, in the same way. The relation between man and his environment is a dynamic, not a passive, one.

**Human Mind—the Picture of Man's Achievements, Past and Present.** The mind, consisting mainly of patterns developed in our internal behavior mechanisms, responds very quickly and sensitively to environmental objects and the stimuli which they present. So true is this that, as we said above, the mind of any individual at any one time is a sort of behavioristic "picture" of the environments which have operated upon it. But this "picture" is not alone of the environments of today, but also of the whole of his past life. All of the things which one meets throughout his life go to make up his mind. Thus, the mind is a great complex integration of acquired behavior patterns, with a few strands of instincts and reflexes serving to tie together what is acquired and root it or condition it to the organism. Because the content of the mind is so largely acquired, it changes as we go from environment to environment. And people who live under the influence of different, but relatively constant, environments have different minds. The Indians in America, the Chinese in Asia, and the English in Europe have quite different mental contents, although they have very much the same inherited neuropsychic technique or native behavior processes. On the other hand, members of these different peoples have much the same minds when brought up under the same or similar environments. But it is necessary for them to be brought up under similar environments from infancy if they are to have like minds, because as we said before, mental responses of the early years persist and are eradicated with difficulty, if at all. You can never make people act and think alike if they have previously spent their formative years acting and thinking in unlike ways. Their different environments in the meantime have caused them to acquire different behavior patterns.

**Relation of Mind to Culture.** All of these acquired mental habits and their corresponding overt responses, and the physical and social inventions of a people taken together, constitute their culture. This culture is, therefore, both material and non-material or spiritual. The non-material culture is the one most valued by us, because it contains the keys to the material culture. Culture is but another term for our social environments. The material

culture or inventions correspond to the social environments of the first order. The non-material culture, including the social inventions, is synonymous with the psycho-social and derivative-control

I. Types of Animals under Discussion	II. Internal Structural Changes	III. Phases of Neuro-Psychic Technique Dominant	IV. Language Forms Used	V. Processes of Thinking Involved	VI. Phases of Invention Utilized
Human	Inner structural changes are no longer the product of biological mutation and variation, but are in the nature of acquired neural and muscular adaptations and skills. Also sensory and organic extensions produced by inventions serve to differentiate the responses of the organism to its environment.	Projective stage dominant. The mechanisms of internal habit adjustment have been symbolized and projected or externalized in permanent forms as psycho-social controls. Vocal projections also of very great importance.	Written language is dominant. Vocal language still very important. Gesture, pantomime, holophrastic: vocal expressions are now but supplementary or serve only specialized functions, such as entertainment and recreation.	Scientific conceptual thinking probably dominates society, although in volume it is secondary to relatively unsystematic and emotional thinking. Scientific thinking regarding future adjustments tends to become common.	Projective invention is the dominant type and is the basis of modern industry, communication, and social organization. It fosters and utilizes method inventions.
(1) Civilized types					
(2) Barbarian types	The structural changes in brain, hands, vocal apparatus, and upright position begun in the transition stage are now perfected and man reaches his maximum biological development.	Inner symbolic habit response with minimum of overt behavior organization now dominates the adjustment process, especially in complicated situations in the higher stages of culture. Overt habit adjustment still important. Projection of internal symbolic adjustment mechanisms in the form of traditions, beliefs, etc., begins.	Vocal language becomes verbal, i.e., speech is evolved and becomes the dominant language mechanism. Gesture language persists as a means of communication, especially in intergroup contacts. Holophrastic expression is specialized.	Conceptual thinking is well developed on the basis of verbal language among higher types of groups. Perceptions are also well defined through the use of definitely conditioned word symbols. Thinking about the future, where it occurs, is primarily of the nature of wish projections rather than of intellectual analyses.	Empirical inventions become complex and are guided by the internal habit or thinking processes. But as yet man is not able to make projective inventions on any basis other than speculative magic and generalizations from random experience.
(3) Savage types					
Human begins	The highly differentiated brain, hands, and vocal apparatus, and the upright position, which distinguish man from the lower animals and enable him to develop language and thought and thus to transform his natural environments largely into physico-social and bio-social environments and to create a psycho-social environment, begin and reach a large portion of their development in this period.	Transition stage from the total overt habit response with minimum of internal behavior organization to the internal and symbolic habit response with minimum of overt organization. Overt habit adjustment still dominant. Inner or symbolic trial-and-error learning begins.	Gesture language develops but remains simple and carries little imaginal content other than kinesthetic. Simple vocal cries, approaching the modifiable holophrastic content, also serve to convey emotional attitudes and suggest or stimulate like coadaptive or antagonistic responses.	Perceptions through the higher exteroceptive senses lack the definition which verbal symbols as yet not invented, would give to them. The nearest approach to abstract thinking is probably in some approaches to generalized pattern responses.	Simplest accidental or empirical inventions seem clearly established but apparently they occur without foresight of their use.
Prehuman ends					
Primates (Domesticated animals?)					
Median animal types	Lengthening of the life period improved means of locomotion and improvements to the sensory equipment bring the animal into wider and more complex and more rapidly changing environments, making it necessary for it to develop overt habit patterns to supplement the old instinctive patterns which no longer meet the requirements of more complex adjustments. Increased and more flexible cortical development makes possible the organization of new habit-adjustment patterns.	Habit modifications in adjustment initiated from without and executed as total overt response. New adjustments made predominantly on overt trial-and-error basis. Minimum of internal control over the adjustment process, although neural mechanisms are developed as a means to adjustment.	Total overt responses and cries and other sounds and emotional expressions serve as stimuli to initiate responses in other animals, but there is apparently little or no provision of the results of such expression. Response to gesture is still rudimentary.	Vague perceptions only, without any recognition of meaning or any purposive thinking to aid in adjustment.	Some simple accidental modifications of the physical environment occur in the process of adjustment, but such modifications are not foreseen and probably are not reserved. Unforeseen social adjustments due to changes in habits apparently are sometimes perpetuated.
(1) Vertebrates					
(2) Higher invertebrates					
Lowest animal types	Close correlation between structure of the organism and the environment to which it adjusts itself instinctively. No need for habit modification.	Instinct is the only neuro-psychic technique. Response is stereotyped.	There is no language proper, although responses of one organism serve as stimuli to like or unlike stereotyped responses in other organisms.	No conscious processes.	None.

Figure 116. Chart Showing Evolution of Mind and Associated

environments, although the latter type of environments also overlap with the material culture. The material culture is largely self-perpetuating. That is, it will persist through a number of gen-

erations without renewal. But ultimately it must be preserved or reconstructed through the psycho-social environments of non-material culture. The non-material culture is carried down from

VII. Types of Environment Operative	VIII. Types of Adjustment Response Function- ing	IX. Objectives Sought in Adjustment	X. Types of Social Organi- zation
Psycho-social environment is deposited in externalized symbols and dominates and directs the physico-social and bio-social environments. The natural environments operate almost wholly indirectly through the bio-social and physico-social environments.	Rational responses, making use of the data of science and the symbolic patterns of tradition, are dominant, but emotional responses are by no means negligible.	To the future as well as to the present and with reference to the race as well as the individual. Narrow hedonic motives in adjustment probably predominate. Religion tends to be transformed from a fear motivation to a constructive humanitarian ethical philosophy.	Social organization becomes very complex and purposive. Groups expand from the category of primary and face-to-face groups to the most abstract derivative types of "publics" and closely organized administrative groups. All aspects of life become highly organized, but flexibility of organization is greater than in the preceding stage. The economic life is most highly organized, but the political is a close second to it. Educational, recreational, religious, and aesthetic organization follow in complexity. Vastly increased means of communication extend the range of groups and their abstractness as well as increase the complexity of their organization.
The psycho-social environment takes on definite form. Its content is vocal, and it is organized as traditions, conventions, beliefs, mores, etc. It begins to assume direction over the biosocial and physico-social environments, which reach a considerable degree of development as means of mitigating the severity of the impact of the natural environments upon man.	Trial-and-error adjustment responses are largely transferred to internal mechanisms, leaving the total overt response for the end process of adjustment as the result of thinking out the behavior. However, scientific thinking has not yet superseded sympathetic magic as a system of making adjustments.	The ends or objectives of adjustment still remain almost wholly in the present, but the human animal has reached the stage of internal habit control, or thinking, at which he is able to see his adjustment to the present more or less as a whole. Religion, as a philosophy of adjustment, is based on considerations of fear and personal intrigue.	Social organization becomes more complex and conscious and purposive. Organization is still primarily on the basis of the primary group because of the limitations upon means of communication. Derivative group organizations arise, especially in the political sphere, but come together in face-to-face association, at least through their representatives, upon occasion. Religious and political organizations are, perhaps, most dominant, although economic organization is also very important. Organization, although based mainly upon habit, is almost as fixed as if instinctive, because of the dominance of custom and tradition.
Psycho-social environment can scarcely be said definitely to exist because the means for symbolizing and objectivizing experience are so crude and rudimentary that the fund of culture is extremely small or non-existent. The physico-social and bio-social environments are still extremely crude and offer but little protection against the direct impacts of the natural environments.	Trial-and-error the predominant form of adjustment response, but there is a slight beginning of the transfer of these to the internal mechanisms. Instinctive responses are still the chief forms in the lower or prehuman phase of this stage of development.	Hedonistic satisfactions of present desires are the only conscious objectives in adjustment.	Instinctive collective responses are now somewhat supplemented by group responses based on habit adjustment, but there is little or no purposive element in group behavior. Group response centers almost wholly around food, fear, and sex impulses.
Only rudimentary beginnings of physico-social and biosocial environments. The natural environments are dominant.	Trial-and-error as a method of adjustment begins to take the place of instinct.	Apparently little or no foresight of even the most elementary hedonistic satisfactions.	Groups of individuals responding to similar stimuli or to one another, to some extent on the basis of purely overt habit mechanisms, but mainly on an instinctive basis, in search of food, protection, and sex satisfaction.
Natural environments only.	Responses stereotyped.	None.	Instinctive group responses only to food, sex, and protective objects. Such responses are very rudimentary.

Objective Forms. (Courtesy of the *Journal of Sociology*.)

one generation to another, or broadcast through language from one person or group to another.

Language is the universal vehicle by means of which non-

material culture is carried. In fact, in its objective form, the non-material culture is organized in the form of language. We find it expressed either in the form of traditions, conventions, or books, in literature, art, science, or law, or in similar forms. And these use either vocal or written carriers or mediums. Only verbal language is effective in carrying a high grade of culture, because only it can objectivate the subjective or inner habit (mental) aspects of culture and give those aspects definite oral and visible form.

**Culture a Group Possession.** Since culture is an aspect of mind, necessarily it is a product of the social environment. Not all of the culture of a people is the possession of any one person. Especially is this true in modern life, which has become so complex. Culture is a group possession and it is carried by the group. Each member of the group carries or possesses some part of the total wealth of culture belonging to the group and can convey it to other members of the group by direct physical contact or by means of language. The group itself consists of a number of people living in sufficiently close or functional contact with one another that ready communication, either by oral or by written language, takes place among them. Thus, each individual in the group acquires his culture by communicating, mainly through the medium of language, with other members of the group. As a consequence, the non-material culture—and the material culture also—comes to be more or less uniform within the group. The culture of the group is intercommunicated within the group. This interchange of culture, through language symbols and systems, gives rise to responsive mental or neuro-psychic behavior. In fact, it is responsive mental behavior of the members of the group. This responsive mental behavior we call the “group mind.” If the responsive behavior is also uniform or like behavior, we say the group mind is unified and we speak of group or public opinion.

**The “Group Mind.”** Of course, it is not necessary to tell the reader that the group has no single mind in the sense that an individual has a mind. The term “group mind” is just a metaphorical expression, but it is a short and expressive way of

saying that the members of the group have the same non-material culture, or that they think together or alike. Another meaning sometimes given to it is that people in the same group are responding mentally to the same culture or thinking about the same or related things, although they may not be responding or thinking alike on these matters. The "group mind" also differs from the individual mind in another important respect. Its functioning is not terminated with the death of the individuals constituting the group. As long as the various environments remain the same for a group, its culture will continue the same, because individual minds keep on responding in much the same way to the culture which persists in their group. However, the "group mind" may change rapidly and markedly over a relatively short period, because individual attitudes have changed, due to the impact of a powerful new environment, as in the case of the entrance of a peaceful people into war.

**Science and Culture.** The importance of science in our culture is becoming increasingly apparent. Thus, the schools in particular are teaching the sciences more than ever before, and the traditional subjects and culture less than formerly. The culture of the church is still more traditional than scientific, but it also tends to change. All of these institutions or carriers of culture are slowly being transformed under the influence of scientific criticism. It is especially difficult to subject the press to tests of scientific accuracy. The difficulty with the press is not so much that the culture it carries is traditional, as that it is so frequently trivial, or inaccurate in content, or even perverted for purposes of propaganda. Yet the press plays such a large part in moulding the "group mind" that it is very important that its cultural content be made trustworthy and dependable, even if some sort of institutional control has to be applied. Much the same may also be said of the movies and other means of influencing individual and group behavior.

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  3. What are the two classes of environmental stimuli or pressures included in the general type of "natural environments"?
 

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  4. What are the two classes of environmental stimuli or pressures included in the general type "social environments of the first order"?
 

See references to Question 3.
  5. What is meant by physico-social environment?
 

See references to Question 3.
  6. What is meant by bio-social environment?
 

See references to Question 3.
  7. What are the three classes of environmental stimuli included in "social" environments of the second order?
 

See references to Question 3.
  8. What is meant by the psycho-social environment that depends on gesture?
 

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  9. What is meant by the psycho-social environment that depends on vocal language?
 

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  10. What is meant by derivative control and institutional environments?
 

See references to Question 3.
  11. What is the effect of all the cultural or social environmental pressures on the neuro-psychic adaptive mechanisms of the individual?

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## CHAPTER XXVII

### CULTURE—SUBJECTIVE AND OBJECTIVE \*

**Need for Definition of Term.** The word "culture" has so many different meanings that it is necessary when one uses the word to define clearly with just what significance the term is employed. For example, we often speak of culture, meaning personal development—the distinctive mark of education, training. Although this is a common use of the word in educational discussion, culture has a much broader meaning when we use it to designate man's social experience. The word as used by anthropologists, sociologists, and other students of man's historic development refers to the ways of living characteristic of a group of people who share a common social experience at a definite time and place. Thus, in its more technical sense culture designates *the content of social experience*. For example, we speak of the culture of the Bushmen, or of the American Indians at the time when Columbus landed, or of the modern Frenchmen. A good illustration of the meaning of culture, when it is used to cover the distinctive manner of life of a body of people, is the account of the customs and social conditions of African people living in the valley of the Lower Niger as given by Major Arthur Leonard in his fascinating book, "The Lower Niger and Its Tribes." This description of native life includes not merely traditions, customs, organizations, and social habits, but also the mental attitudes that are peculiar to the people living in this African environment. The author, by his interpretation, is trying to present as clearly as possible the life of the people—that is, their culture in the sense that the anthropologist uses the term, including *everything that is characteristic of the people as a group*.

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**Two Broad Aspects to be Considered.** It will help us in our understanding of culture, using the term in its wider sense, if we distinguish its two aspects—the objective and the subjective. By the objective element of culture is meant not alone the tools and utensils that are made by the people, to the use of which they have been accustomed; it includes also the modified trio-environment, the objective in the social and psychical, as these are discussed in the preceding chapter. By the subjective is meant the conditioning effect of social experiences; the influence of beliefs that have grown up and become the traditional material as these become evident in the patterns that control the behavior of every child born into the group. The world of ideas has its objective side; it becomes subjective when it finds a place and expresses itself in the mental life of the individual.

### Objective Aspect of Culture

**Implements and Material Resource.** The study of a people's culture on the objective side is expressed in material things in so far as this can be separated for the purposes of investigation from the larger cultural life. It concerns itself with tools, implements, methods of agriculture, the construction of houses, the manufacture of weapons—indeed, all the material resources of the group so far as they are characteristic because of their general use. These material productions and these methods of doing things constitute a vast and valuable social heritage which is handed on from generation to generation and in no small degree provides the means for social survival. Some of this possession is the result of inventions and discoveries that were fortunately incorporated in the life of the people and slowly developed by improvement until they became essential for the maintenance of a definite culture. If this objective culture could not be easily transmitted, there would be no possibility of social progress.

**The Body of Common Knowledge.** But there is another side to objective culture. Important as it is to preserve the tools that have been made by the great effort of some of the people, it is the knowledge of how they have been made that has the greater

social value. Thus, even in the materialistic sense, culture consists in no small degree of a fund of knowledge that increasingly gives man power over his physical environment and makes it possible for him to fashion or to produce what he needs for his physical security.

**Common Beliefs, Folkways, Customs.** If, therefore, we begin the study of objective culture with our attention entirely upon material products, we soon find ourselves dealing with ideas and tradition that lie behind the things manufactured or the processes carried through. The literature of savage society is replete with illustrations. When the Baganda native, for example, wished to cut a tree for the building of a dug-out canoe, he asked "the medicine-man near at hand to consult the oracle and to tell him whether he might venture to fell the tree. There was no question of timber-rights, or of ownership over the forest, for all timber was public property; but most people held the belief that the trees were possessed by spirits, and that the spirits needed to be propitiated by an offering of a goat or of a fowl, with some beer and possibly a few cowry-shells. The cowry-shells were tied around the trunk of the tree, the beer was poured out at the roots of it, and the animal, if it was killed, was killed in such a manner that the blood ran to the roots; the meat was then cooked and eaten by the man who made the offering, seated near the tree. In some instances, the goat was kept alive, and allowed to roam about at will in the garden in which the tree grew." Marett, in *Among the Head-Hunters of Formosa*, tells us that "among the Bunun, as also among all the tribal groups of the great Taiyal 'nation,' there exists the peculiar custom of starting a 'new fire' at the time of the sowing and harvest festivals. This 'new fire' is ceremonially kindled." These ideas themselves are a social heritage; they belong to the objective side of culture, for the individual discovers them as he explores his environment and comes to know through personal contact the circumstances around him due to the experiences of the group into which he has entered by birth. The effect of their discovery on the individual is subjective, as will be explained later.

**Common Ideals and Aspirations.** It is through this handing on from generation to generation of beliefs and ideas, objective

in their origin and method of transmission, that the general fund of civilization grows. The existing fund is made up of contributions by individuals which would be of only temporary advantage to society were it not possible to transmit them from one period to another. Although the invention, discovery, superior technique, or new idea springs forth from the individual mind, it takes objective form when it is made a deposit in the ever-accumulating general knowledge that is carried forward as a group possession. It becomes the most precious resource of a race of people because as social pressure it operates to mould the individual. It does more than preserve the past; it stimulates individuals, as they become acquainted with it, to make further contributions. In this way, not only does the life of a people have past experience for its foundation, but also the future unfolds from happenings in the present that are the direct result of experiences of the past, carried on by social transmission. In this sense the common ideals and aspirations are objective culture.

### The Subjective Side of Culture

**As Applied to the Individual.** When we turn to the subjective element of culture we immediately change our point of view. Now, instead of directing our attention to the fund which preserves social experience and constitutes what we mean by civilization, we consider the effect on the mind of the individual—who, through social experience, enters into the heritage of the group and has his personality changed by his effort to bring himself into harmony with the ways of his people. In this way the individual plans to adapt himself to his social environment and is forced to bring his impulses under social discipline and cultivate ways of behavior that have the sanction of the group. By association with other people about him, particularly his parents, the individual becomes acquainted with the social possessions that have been stored and transmitted as the culture of the group. The individual is not free merely to inform himself of the existence of these social accumulations of material objects, beliefs, and traditions; he soon finds by social pressure that he must act in the ways that conform to his social environment.

**Reactions of the Child.** The individual mind, especially during the formative years of childhood, does not easily or quickly adjust itself to the social demands put upon it by the surrounding objective culture; the child enters his social situation with an equipment of impulses that express themselves in behavior not at all in harmony with the settled order of things or the expectations of his elders. Immediately, the social group, by such methods as punishment, reward, and suggestion, attempts to stimulate the activities that are desired and to suppress those that are not. Thus begins the process of transmitting the social heritage to the individual so that he personally will possess the culture which the group has accumulated. It is a faulty process carried on with difficulty; for the individual balks at the discipline imposed upon his inclinations, and those who bring information to him as to the group's possessions and demand that he conform his actions to the line of group behavior are impatient with his failures to respond.

**Conflict between Unsocialized Child and Socialized Adult.** It is in just this way that the young and the old, those taking on social culture and those who are adjusted to it, become involved in the characteristic conflicts that always attend the effort of one generation to teach the young that are to follow them. Quite naturally the child would react to stimuli in characteristic ways following his inborn or unsocialized tendencies—having no regard for the mores, the folkways, laws, or institutions of his social environment. And just as naturally, the socialized adult seeks to bring social pressure to bear on the child to teach him new responses, and to make these life habits so that his characteristic reactions will cause the social group to be friendly toward him, and to fit the child to lead a useful life in the community. The appeal of the wise parent or preceptor is through the interest of the child—first getting his attention, then modifying his behavior mechanisms.

**Culture as a Product of Reaction of Inherited Equipment to Environment.** Culture in the subjective sense means, therefore, the process by which the content of social experience is incorporated in the unformed mind as a result of contact with the

social environment. It is during his early years that the individual subtly acquires this social culture; when maturity is attained and habits settle themselves, it is exceedingly difficult for the adult to respond to new forms of social experience. Because of this fact, we have to turn to the child to see subjective culture in the process of being made.

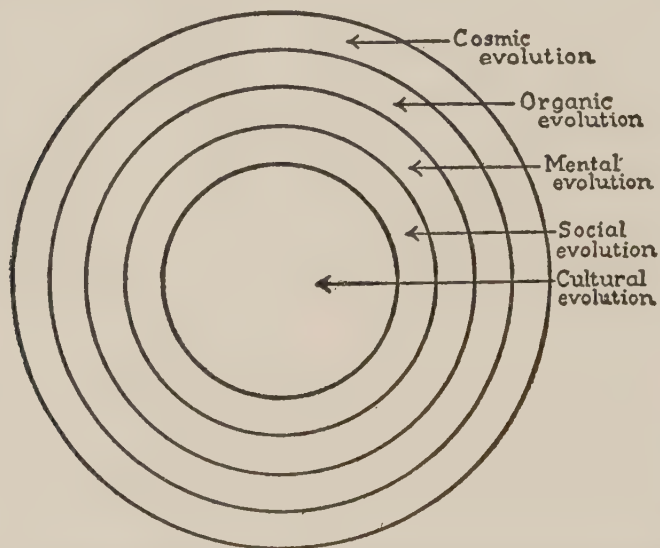


Figure 117. Diagram Showing Phases of Universal Evolution. (From Ellwood.)

**Not Merely a Stamping Process.** It must not be thought, however, that this experience is only the registration of social pressure upon the mind of the individual. Subjective culture is not a mere stamping process, by means of which the individual is marked with the characteristics of his group; each individual brings to the process an indispensable element without which there could be no cultural product at all. What happens is like the response of the plant to the surrounding sunshine; the environment provides the means of stimulation; the responses that are made are the result of the power of growth which is inherent in the individual.

**Individuality a Factor.** The human being starts life with certain tendencies of action and of feeling that are easily aroused

by appropriate stimuli; some of these tendencies are common in human experience and seem so characteristic a part of human nature that they are often called instincts. Since man so early in his life receives the modified influences of the social environment and responds to it, it is exceedingly difficult to determine how much of his behavior can be charged up to original instinctive tendencies. Experimental knowledge regarding this problem of instincts is very hard to obtain, but in so far as we have been able to get at the facts by experiment or observation, it appears that much of man's behavior, which in the past has been

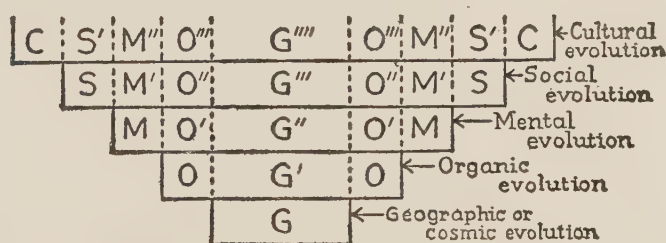


Figure 118. Diagram Showing Relation of Higher to Lower Phases of Evolution. (From Ellwood.)

considered instinctive, is in part a social product, a modification through social contacts of the mental equipment with which he started life. It is evident, however, that the mind takes over the outside culture because of inherent need; the individual has desires which the group is able to satisfy by drawing on its fund of experience and conveying this material to the developing mind which is to be adjusted to its social environment.

### Culture as Socialized Intelligence

**The Product of the Search for Truth as Order.** Culture is discussed in this chapter in its subjective aspects, as the effect on the neuro-psychic mechanism of the process by which the mind is developed through social contact. So far as this cultural process is a response to an inborn disposition, it relates to the tendency toward order which has already been enlarged upon in chapters discussing "order as condition precedent to life"—order as the first law of nature. Mind may be thought of as a manifestation of this tendency. The mind craves order, that

its conscious experiences may have meaning. This demand for order may be thought of also as the first law of all life—life being conceived as one of the ways in which energy manifests itself pursuant to natural law. The predisposition that comes to expression after birth provides momentum for mental growth; it must have been this that Matthew Arnold had in mind when he described culture as having its origin, not in the instinct of curiosity, but in the love of perfection, or the sense of need for order. Culture becomes, therefore, a product of the mind's inner impulses as directed by social influences out of the environment. Thinking thus becomes a search after truth as order, and the product of thinking is an increasing intelligence. From this point of view, culture can be regarded as socialized intelligence.

**Primitive and Modern Culture.** It is evident, therefore, that subjectively there can be no essential difference between primitive and modern culture. Savage society gives us a more simple picture of the process by which culture becomes a mental possession than does the modern, civilized group; but if the savage transmits his culture by the same process that we do ourselves, he also brings to the experience a full endowment of mental equipment. His greater poverty of social resources explains the meagerness of his cultural development. The anthropologist is firm in his insistence that the savage is not lacking in human capacity or deficient in any of the inborn impulses that influence behavior. It is rather that the savage lacks the quantity of social resources, the objective things in culture, that modern man has gathered as a result of his superior social experiences; likewise, modern man excels in the quality of his cultural experiences. The consequences of this difference in the social resources that modern man inherits as compared with his savage brother appear in the superior mental equipment developed in modern man; his mind is better prepared to deal with his experiences because those that have been transmitted to him from the accumulation of the group have stimulated to activity a greater proportion of his original mental equipment for life. Thus, the study of savage culture reveals the fact that social life is a product of mental endowment plus the possibilities of the social environment. It is the world which modern man has formed

that explains his more complicated and higher culture. He is thrust by birth into a more complicated environment and given the advantage of a superior collection of facts; he responds mentally to the circumstances in which he is placed.

**Handicap of Primitive Man.** The handicap of the savage appears when we notice the dualistic interpretation he makes of his experiences. A part of his culture has to do with utilitarian interests. In activities of this sort, like modern man, he is attempting to use his resources of mind to manage successfully enterprises that make possible his adaptation to environment. Here we find a faint beginning, an elemental type, of applied science. Alongside of these useful activities, which are actual processes of adjustment to concrete situations, we find the savage developing a magical formula for the control of forces beyond his power, or forces which he controls without understanding the means by which he accomplishes his purposes. The void of knowledge is filled up by contributions from the mind itself, which demands satisfaction. It is this that explains the great quantity of magic material which appears in savage culture; it is not the product of an abnormal or peculiar human equipment for life, but rather the spreading of human wish into the territory where the feeble knowledge of the savage has not been able to penetrate. It is easy to see that the savage's ignorance of physical and social facts forces him to fill the emptiness that crowds upon his small fund of knowledge with all sorts of magical content, in order to satisfy the mind's craving for order and system. Thinking results from the craving of the mind for order. And when the individual or group is ignorant of the nature and content of the universe, myths, superstitions, and unfounded beliefs become the objective materials of culture; and subjective culture becomes the product of social pressure misguided by false ideals that stand in the way of progress and ultimately lead to conflict when solutions of problems based on knowledge of environment are proposed.

**Superior Cultural Advantages of Individuals in Civilized Society.** As experiences accumulate and the mental equipment of a group of people progresses toward civilization and is stimulated to greater discrimination in dealing with problems, the

area occupied by magic is reduced and gradually science takes its place. As a result of the rapid increase in the efficiency of science and a clearer recognition of its superiority as a means of dealing with demands for adjustment that press upon man, science, in these days, has become dominant as a social factor influencing culture. It must not be forgotten that science satisfies the inner need of the mind as well as provides effective means of control of physical circumstances. Science is a trustworthy means of reducing human experience to order and understanding. It now influences man to such an extent that it can be called the basis of our modern culture. When the human infant comes in contact with his environment in our time, he is at once influenced by conditions which are the result of modern science. His mental equipment is shaped by stimulations that are in part the product of a rapidly increasing science. It is of utmost importance that, as he pursues his way through courses of higher instruction, the student should come to have an appreciation of the outstanding contributions that make up the complement of premises for scientific reasoning. Thereby the subjective achievements, the learning processes of today, become a part of the objective culture of tomorrow.

**Means of Transmitting Culture a Social Necessity.** Culture as a process by which man is fitted to adjust himself to the opportunities of his environment is a social necessity; it provides the basis for the perpetuation of peoples and makes progress possible. Culture is not a covering wrapped about human nature, but something inherently necessary, which is incorporated in human nature itself, the product of the mind's equipment in its contact with the social environment. Culture is the process of social growth; in the words used by Montesquieu to describe the impulse to study, it is "the desire to augment the excellence of our nature, and to render an intelligent being yet more intelligent." Because the aim of culture is to enlarge the capacity of individuals and groups to order their lives socially, as a discipline, it necessarily takes on many forms. The ways by which culture in all its varying forms is transmitted from generation to generation are all included within the meaning of "education." In this broad application education means not alone the curricula, the

materials, the techniques, the agencies for training in childhood and youth, but all the group arrangements for discipline and social adaptation, all the habituating procedures consciously employed by social groups—industrial and social as well as pedagogical—that cover the full range of individual and group experience. The educative process, and the several forms of training through which culture is inducted and transmitted are subjects too large to be dealt with here, although these must be considered a part of the general theme, culture.

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## CHAPTER XXVIII

### PERSONALITY—THE PSYCHOLOGY OF SELF-ORGANIZATION \*

**What Is Meant by Personality.** Man may well be called the self-conscious animal. As soon as an individual begins to be aware of an interest or interests, he begins to evaluate his experiences—his ideas, his perceptions, his beliefs—in terms of self, and to evaluate self in terms of that which is objective; he begins to create in his own mind, and at the same time in the minds of his fellows, a notion of what he is. Each individual, as soon as he is aware of the fact that a relation exists between himself and other individuals, comes to know himself in terms of these relations. It is the sum-total of the distinguishing characteristics of an individual, together with their evaluation by himself and others in terms of social worth, that we think of as personality.

**Popular Uses of the Term.** The term “personality” has many uses—both popular and scientific. The popular use, however, has in it the elements or essentials around which scientific conceptions are built. They include such ideas as: personal magnetism and sex appeal; individuality or attractiveness due to difference; aggressiveness—drive; social intelligence—good social sense; sociability—being a good mixer; etc. Something may first be said with respect to each of these component elements of the self.

**Personal Magnetism and Sex Appeal.** We say a certain person has an attractive personality, another has a strong personality, another has lots of personality, another possesses “personality plus.” What do we mean? One synonym is that potent in-

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definite something called "magnetism." Some persons are blessed with personal magnetism that is "irresistible." They have "it." Their personal charm attracts inevitably to acquaintance and friendship. They are always centers of attention. At any social gathering they are "the drawing cards." They are full of life—and life is intimately related to sexual energy or libido.

**Individuality—Attractiveness Due to Being Different.** A second use of the term when applied to the normal minded is to call attention to that individuality which helps to make a person interesting. There is an attractiveness in being different if the variation is socially acceptable. Originality promotes a distinctiveness which breaks the monotony of social contacts among people, who, after all, are so much alike as to be tiresome. Some individuals strive to cultivate eccentricities that will set them apart from homogeneous mankind. Thus, Lord Byron refused a sumptuous banquet in favor of potatoes soaked in vinegar; George Sand smoked cigars; Vladimir de Pachman chatters and "makes faces like a monkey" while he is playing the piano—at one performance he omitted his antics, much to the disappointment of the audience. The person who is different contributes a new and welcome patch to the crazy-quilt of society.

**Aggressiveness—Drive.** A third aspect of normal personality is aggressiveness. The man of ambition who is always forcing his way into the foreground may be repulsive; but there is no denying the fact that he has a capacity for securing attention to himself—and ability to attract and hold attention is one of the chief qualifications of leadership. He is the "go-getter," "the life of the party," always full of "pep" and animation, always alert and eager to join in any available activities. Ex-President Coolidge lacks a striking personality because he is devoid of the drive that impels a man to come forward and assert himself vigorously on all occasions; the American Presidential office does not call for leadership. Senator Borah, on the other hand, is impressive because he is continually taking a firm stand on political questions and expressing his views in no uncertain language. Mark Hanna was an aggressive leader of quite a different kind—but a leader. Aggressiveness is a large element in successful

leadership, whether in deliberative assemblies, organization of the machinery for focusing attention on a public need or executing a policy or plan of action.

**Good Social Sense or Judgment.** A fourth characteristic of normal personality is social intelligence. Social intelligence is not to be understood as meaning intellect—mastery of knowledge or capacity to think; for the scholarly recluse, the learned man, by virtue of his solitary ways, frequently misses that refinement of the rough edge that can only come through plenty of social contacts. By social intelligence is meant: the ability to adapt oneself to the demands of the social environment; the capacity to see what people want and what they admire, and the power to summon one's resources in ways most effective for winning popularity; the sort of brightness that manifests itself in wittiness and cleverness. The intelligent person knows the right thing to do at the right time; he has well-organized social feelings and intuitions as well as sound social judgment. Deliberate thinking about concrete situations is required.

**Sociability—Being a Good Mixer.** A further aspect of individual behavior to be included in a broad conception of personality is sociability. The sociable individual is a good mixer, he makes friends easily, and he knows how to convert chance acquaintances into lasting attachments. He has a winning way. He has a sense of humor which amuses others and which allows him to keep his own poise in situations embarrassing to his ego. The attractive personality knows the art of conversation—how to listen and how to speak in an easy and interesting way. There is none so dull as the man who shuts up like a clam and who utters inanities when he does deign to speak. The individual who is entertaining is marked as a man with personality. Sociability is, perhaps, the trait we most often identify in our daily lives with "personality."

## Conceptions of Different Scientific Schools

**Value of Studies in Abnormal Psychology.** Scientifically, personality refers to the psychical aspect of an individual as this is embodied in thoughts and expressed in behavior. In its sev-

eral uses the word may be synonymous with such other words as mind, soul, spirit, the dominant self. Conceptions of personality include abnormal as well as normal states. In mental disorders of a dissociative type, there frequently occurs a change of personality—a change in the dominating self, thereby operating to correspondingly change the whole attitude and behavior of the individual. The alteration which comes about in these abnormal changes of personality cannot be understood until there is a comprehension of the structure and functioning of the parts involved in the transition. Our understanding of personality has been very much enlarged by scientific inquiry into the make-up and workings of the abnormal mind. That branch of science called abnormal psychology has shed much light on the normal mind as well.

**Scientific Approach.** All psychological analysis of personality leads to the conclusion that what we call personality is in the nature of an organization. In our treatment of the scientific aspects of the subject, therefore, our prime purpose will be to indicate that integration is the essential aim of all those educative processes associated with mental development; that this integrating process comes about as result of an effort to reconcile conflicts—conflicts of instincts and emotions, conflicts of ideas which lead to temporary and finally to more permanent adjustments. There are various scientific conceptions of the nature of personality. We shall consider here only three: (1) the psychological, (2) the ethical, (3) the legal—indicating in each case, that personality is essentially a matter of organization. The psychological conception is first considered, following which the moral and the legal conceptions will be discussed. Scientists in their analyses have made quite different approaches or have given quite different emphasis to the facts correlated in the psychological conception of personality. We may make brief mention of three different schools identified by the names behaviorists, structuralists, and functionalists.

**The Behavioristic School.** The behaviorist is interested only in the stimuli and responses involved in all action. He is not interested in the rôle of the mind in behavior; for he leaves consciousness out in the dark either because he cannot see it or

because he believes it does not exist. Personality, for the behaviorist, would be treated in this fashion: The child is hungry; he cries; the mother hears him; she responds by supplying food; the child eats and is satisfied. The mother has become a pleasant stimulus and the child likes her. Thereafter, other people who resemble his mother win his favor through the medium of conditioning. Thus, through associations, certain personalities appeal to him because they remind him of his mother.

Personality is a stimulus which evokes a repertoire of appropriate responses. Now what, according to Watson, is this repertoire? "Personality," he says, "consists of an individual's total assets (actual and potential) and liabilities (actual and potential). By assets we mean: First, the total mass of organized habits, the socialized and regulated instincts, the socialized and tempered emotions, the combinations and interrelations among these; and second, the high coefficients both of plasticity and retention. By liabilities we mean similarly that part of the individual's equipment which does not work in the present environment and the potential or possible factors which would prevent his rising to meet a changed environment."<sup>1</sup>

**The Structuralistic School.** The structuralist confines his study to the make-up of consciousness. Of what does it consist? Just what is the structure of mind? His method is analysis by introspection. His viewpoint tends toward the philosophical treatment of personality as made up of various selves. James' description of the material, social, and spiritual selves is a case in point. The structuralist takes a cross-section of personality in contrast to the longitudinal section taken by the functionalist. The structural theory is inclined, therefore, to be static, again in contrast to the dynamic conception drawn by those assuming the functional view.

**The Functionalistic School.** The functionalist, like the behaviorist, is primarily interested in the question—What does personality do? Unlike the behaviorist, however, the functionalist is fundamentally concerned with the part that mind or con-

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<sup>1</sup> J. B. Watson, *Psychology from the Standpoint of a Behaviorist*, p. 397. Lippincott, 1919.

sciousness plays in aiding the organism to adapt itself to the changing demands of the environment. The functional approach is evolutionary. What is the function of the mind in the process of adjustment? The functionalistic school deals with personality in terms of instinct and habit. Personality, for them, is built out of instinctive nature as it becomes modified by experience.

**Relative Importance of Each Approach.** Now, the lines here drawn between these three schools are somewhat artificial. For example, it is difficult to distinguish between what personality is and what it does. Assuming that personality is a determinant of behavior, the only way we have of getting at structure is by studying functions. Similarly, it is unfair to describe the self as static, since the self is generally regarded as a dynamic entity. Looking at the matter relatively, however, the instinct view is the more dynamic. Again, the view of personality as an organization of instincts is very close to the structural viewpoint,—considering instincts as the blocks of the mental structure.

### **Conflict as a Factor in the Evolution of Psychological Order**

**The Self Idea.** It is futile to try to make hard and fast distinctions between the various schools. They are really all treating the same object, only approaching from slightly different aspects and employing a different terminology. On account of the confusion that might arise if we sought to study personality on the basis of distinctions so artificial in their nature, we shall disregard the different schools in the following discussion and utilize two modes of treatment which it is believed will be more fruitful in their results: first analyzing personality in terms of selves; and then carrying on the analysis in terms of instincts.

**The "Person"—A Bundle of Selves.** Personality may be regarded as consisting of a myriad of selves bound into a mental unity by one dominant self. A good illustration of what is meant is found in Rose's "Personality of Napoleon," each chapter of which is devoted to a different aspect of this remarkable genius. Each moment finds a unique self, yet all the selves are knit

together in a continuity of experience. "This self-awareness and this recognition of the past experience as one's own is the fundamental and most troublesome fact of memory."<sup>2</sup> Personality types are differentiated on the basis of the dominant self which gives a unity to the continuum of ever-shifting selves. "The self, then," states Brightman, "is not a mere unity (as the soul-theory held), but it is a synthesizer of unity and multiplicity."<sup>3</sup>

**Each Self an Organization for Handling a Particular Kind of Situation.** We may interpret a self as an organization of capabilities for handling a particular situation—while personality is a unification of different selves. According to Doctor Calkins, the self psychology is "a psychology which studies the totally integrated individual in the attitudes with which it confronts its environment."<sup>4</sup> Thus, a particular self is so coordinated that it experiences fear, anger, and love in definite forms with respect to certain objects in a concrete situation. As a father, for example, I love my child, I am anxious for its welfare, and I am angry toward anyone who injures its well-being. As a son, I love my parents, I worry over dangers that may beset them, and I am indignant toward those who do not treat them justly.

**Self Organization as Psychological Order.** Each self is organized in order that its activities may proceed in orderly fashion. I cannot play and work, study and daydream at the same time. "Although these separate trends may operate alone, or at separate times, so far as the entire organism is concerned, its principal survival possibility is its capacity to attend *in toto* to the situation and, using all its powers, get food, escape danger, catch its prey, seek its mate, fight for its own or its mate's existence, or perform whatever other act the moment demands and its powers make possible."<sup>5</sup> Each self is an organization and all the selves, as we shall see later, may be coordinated into a unified personality.

<sup>2</sup> W. McDougall, *Outline of Abnormal Psychology*, p. 542. Scribner's, 1926.

<sup>3</sup> E. Brightman, *Introduction to Philosophy*, pp. 191-192. Holt, 1925.

<sup>4</sup> Quoted by W. H. Burnham, *The Normal Mind*, p. 52. Appleton, 1924.

<sup>5</sup> Kimball Young, "The Integration of the Personality," in *Pedagogical Seminary*, 1923, Vol. XXX, pp. 265-267.

**James' Classification of "Empirical Selves."** Selves may be classified according to the types of situations for which they are adapted. Several outstanding psychologists have made much of typical organized states of consciousness which may be characterized as different selves. James has given us an excellent description of the material, social, and spiritual selves.

**The Material Me.** "The *body* is the innermost part of the material me in each of us; and certain parts of the body seem more intimately ours than the rest. The clothes come next. The old saying that the human person is composed of three parts—soul, body, and clothes—is more than a joke. . . . Next, our immediate family is a part of ourselves. Our father and mother, our wife and babes, are bone of our bone and flesh of our flesh. When they die, a part of our very selves is gone. If they do anything wrong, it is our shame. If they are insulted, our anger flashes forth as readily as if we stood in their place. Our home comes next. Its scenes are part of our life; its aspects awaken the tenderest feelings of affection; and we do not easily forgive the stranger who, in visiting it, finds fault with its arrangement or treats it with contempt. . . ."

Instinct "drives us to collect property; and the collections thus made become, with different degrees of intimacy, parts of our empirical selves. The parts of our wealth most intimately ours are those which are saturated with our labor." At the loss of possessions, there is "a sense of the shrinkage of our personality, a partial conversion of ourselves to nothingness, which is a psychological phenomenon by itself."

**The Social Me.** "A man's social me is the recognition which he gets from his mates. We are not only gregarious animals, liking to be in sight of our fellows, but we have an innate propensity to get ourselves noticed, and noticed favorably, by our kind. . . ."

"Properly speaking, a man has as many social selves as there are individuals who recognize him and carry an image of him in their minds. . . . But as the individuals who carry the images fall naturally into classes, we may practically say that he has as many different social selves as there are distinct *groups* of

persons about whose opinion he cares. He generally shows a different side of himself to each of these different groups. . . .

"The most peculiar social self which one is apt to have is in the mind of the person one is in love with. The good or bad fortunes of this self cause the most intense elation and dejection. . . .

"A man's *fame*, good or bad, and his honor or dishonor, are names for one of his social selves. The particular social self of a man called his honor—is his image, in the eye of his own set, which exalts or condemns him as he conforms or not to certain requirements that may not be made of one in another walk of life. Thus a layman may abandon a city infected with cholera; but a priest or a doctor would think such an act incompatible with his honor. . . . What may be called 'club opinion' is one of the very strongest forces in life. . . ."

**The Spiritual Me.** "By the 'spiritual me,' . . . I mean rather the entire collection of my states of consciousness, my psychic faculties and dispositions taken concretely. . . . When we think of ourselves as thinkers, all the other ingredients of our Me seem relatively external possessions. Even within the spiritual Me some ingredients seem more external than others. Our capacities for sensation, for example, are less intimate possessions, so to speak, than our emotions and desires; our intellectual processes are less intimate than our volitional decisions." <sup>6</sup>

**Burnham's List of Selves.** Burnham outlines another list of selves. There is the child self, marked by childish reactions; the social self, developed by exposure to different groups; the educated self, determined by the total education; the business or professional self, trained by one's task; the conventional self, moulded by tradition, custom and convention; the reputation complex as self, consisting in our own conception of what the world thinks of us; and finally, the total self, the outcome of heredity and one's total past, the result of one's central interest in life, one's special ambitions and ideals,—this self is the dominant one, tending to integrate all the others.<sup>7</sup>

<sup>6</sup> William James, *Psychology, Briefer Course*, pp. 177-181. Holt, 1892.

<sup>7</sup> Burnham, *op. cit.*, pp. 47-50.

## Instinctive Desires as Factors in Determining What Is the Dominant Self

**Organization of the Instincts.** According to the instinct theory, personality is founded largely upon innate dispositions which incline the individual to act in certain characteristic ways in response to appropriate situations. McDougall has worked out a list of instincts, each of which is distinguishable by the unique emotional quality involved in its arousal and expressions.

**The Timid Personality.** There is the instinct of flight, more commonly referred to as fear. This impulse is set off by a stimulus to which is given the meaning, danger. When thus aroused, the individual may react in a variety of ways in order to attain his goal, the escape from the threatening object: he may feign death; he may hide; or he may flee. If the avenue of escape is blocked, anger will be aroused—with the tendency to fight. But excessive fear blocks this expression of self; excessive fear breeds the timid personality—becomes a determinant in the development of a dominant self which knits together the continuum of experience as a timid soul.

**The Fighting Personality.** Anger accompanies the functioning of the pugnacious instinct. Any stimulus which means possible injury to self leads a man to fight in his own defense. Anger is a very powerful emotion and for that reason its control is especially important for social relations. An irate disposition which flies off the handle easily and turns readily to violence characterizes the bellicose personality. Such a tendency may be so integrated and socialized that its possessor may perform heroic deeds—become an Andrew Jackson; or it may contribute to the development of a dominant self, producing, perhaps, an anti-social, or an insane, unbalanced personality.

**Erotic Personality.** The sex instinct, or love, if we may believe Freud, is the most fundamental impulse in human nature. Courtship and reproduction occupy a position of importance among human activities. The impulse associated with these is an abundant source of conflict. Sex has been held responsible

for many types of personality, ranging all the way from the depraved criminal to the holiest saint.

**Self-Regarding Personality.** Self-display is another innate disposition. Every man—and especially every woman—likes to attract favorable notice. The individual enjoys “showing off,” demonstrating his superiority, and winning praise. Self-display, carried to the extreme, results in the vain sort of person who craves admiration on slight grounds. This is one of the chief dangers which lie in social circumstances that hold certain individuals at the center of attention—as in the case of one who has acquired great wealth, or has risen through organization to a position of great power, or is the inheritor of class privileges.

**Self-Assertive Personality.** Self-assertion is the instinct that leads a man to look out for “number one.” It is at the basis of aggressiveness and ambition. Given such circumstances as are mentioned above, self-assertiveness may be the tendency which controls the dominant self; by process of integration, a strong personality emerges from the continuum of experience—a Caesar, a Mussolini. A dictatorial type is blessed or cursed with an undue amount of assertiveness.

### Integrations of Selves in the “Psychological Person”

**An Orderly Scheme of Life.** There are other instincts, but enough have been mentioned to indicate how fundamental our hereditary dispositions are in the make-up of our personalities. The instincts, of course, are modified by experience, habits are formed which give a set to the individual, and the plasticity of youth gives way to the retentive cast of age. It is obvious that the various instincts may cross each other's paths in such a way as to constitute conflicting desires. Personality can result only from an integration of the opposing impulses within the complexes and sentiments. “To have a sentiment means more than to be experiencing, just now, a particular group of affective states. It means, and this is the point, that future responses, of a specific character are already prepared. . . . A structure is formed that predetermines experience . . . insures the self against the spo-

radic claims of impulse.”<sup>8</sup> An orderly scheme of life is possible only through the medium of systematization.

### **Conflicts of Selves the One Great Source of Unhappiness.**

The one great source of earthly unhappiness is the conflicts in which our incompatible selves involve us. As we have already noted, each one of us possesses a number of selves which appear upon different occasions. Many a youth who is demure enough before his parents and teachers, swears and swaggers like a pirate among his “tough” young friends. We do not show ourselves to our children as to our club companions, to our customers as to the laborers we employ, to our own masters and employers as to our intimate friends. From this there results what practically is a division of man into several selves; and this may be a discordant and demoralizing splitting—as where one is afraid to let one set of acquaintances know him as he is elsewhere; or it may be a perfectly harmonious division of labor, as where one who is tender to his children is stern to the soldiers or prisoners under his command.<sup>9</sup>

To illustrate—Napoleon had a strong will in regard to his battles and a weak one regarding women. Pitt was a determined statesman but could not resist the lure of drink. Captain John Whitman, who was eventually murdered at sea by one of his crew, was a man with two natures. “At his home in Rockland, Skipper Whitman was mild-mannered and kind, loved by his wife and ten-year-old daughter, and respected by his neighbors. At sea he had none of these qualities. He was a tyrant. There was no language at which he stopped and when a sailor hesitated, he struck, and a blow of his fist was like the thrust of a yard when the ship is caught aback.”<sup>10</sup>

**Diverse Trends.** Diverse trends cannot always be so easily divorced, and when they come face to face, there is strife which demands a settlement. “Man,” Myerson comments, “is a mosaic of wills; and the will of each instinct, each desire, each purpose, is the intensity of that instinct, desire or purpose. In each of us

<sup>8</sup> C. E. Cory, “The Problem of the Individual,” *Journal of Abnormal and Social Psychology*, 1922, Vol. XVI, pp. 374-383.

<sup>9</sup> James, *op. cit.*, pp. 179-180.

<sup>10</sup> *The Boston Herald*, December 11, 1927.

there is a clash of wills, as the trends in our character oppose one another. The united self harmonizes its purposes and wills into as nearly one as possible; the disunited self is standing unsteadily astride two or more horses.”<sup>11</sup>

**Conflicting Drives.** Like the selves, the instincts often war with each other. Two fundamental drives that are diametrically opposed are the desire for new experience and the wish for security.<sup>12</sup> Curiosity spurs us on to seek thrills in new ventures, to find novel sensations that will relieve the monotony of the daily grind, and to take a chance just for the love of a gamble. Pulling in the opposite direction is the longing for security, so much stressed by Adler.<sup>13</sup> We like to feel sure of ourselves even at the risk of leading a dull existence. Confidence in one's safety gives a feeling of “at-homeness” that is very comfortable.

The ego and sex instincts come into constant conflict with the herd impulses.<sup>14</sup> It is the old antagonism between selfishness and altruism. When I want to appropriate objects which do not belong to me, I find that I lose favor in the eyes of my associates; when I wish to give free rein to my sex passions, I learn that society will not approve—and I am very desirous of being well regarded. So there arises a battle between my own selfish impulses and the incentive to win social approval. What is going to be done about it—for some remedy must be brought to bear?

**Temporary and More Permanent Solutions.** Rationalization solves the conflict by so disguising the two combatants that they do not recognize each other. The danger of strife is thus removed—but only temporarily, since a man cannot be so dishonest with himself as to fool himself all of the time. Another remedy is dissociation (mental breakdown). Through this means the two warring camps are completely divorced. The price of disharmony is hypocrisy or dissociation. Neither rationalization nor neurosis are desirable cures because they are only compromises—and expensive ones at that. The sane escape from the dilemma is the more lasting solution—integration.

<sup>11</sup> Abraham Myerson, *The Foundations of Personality*, p. 121. Little, Brown, 1922.

<sup>12</sup> W. I. Thomas, *The Unadjusted Girl*, pp. 4-32. Little, Brown, 1923.

<sup>13</sup> Alfred Adler, *The Neurotic Constitution*. Moffat, Yard, 1921.

<sup>14</sup> J. T. MacCurdy, *Problems in Dynamic Psychology*. Macmillan, 1922.

## Integration of Instincts (Selves)

**How Conflicting Selves Are Reconciled.** Let us see, first, how the conflicting selves are reconciled. The various selves overlap and are intimately interrelated. In some individuals, the selves are largely uncoordinated and even dissociated, in others they are all organized into a single integral personality. Since failure to integrate the various sides of one's nature precipitates painful mental conflicts, there is plenty of incentive to effect a coordination. Integration is secured by the dominant self which brings discordant trends under its sway in accordance with its ideal of what a normal self should be. The ideal self is the supreme unifying force.

**How Conflicting Instincts Are Integrated.** The dominant self not only coordinates the many subordinated selves—it also conditions and correlates the instincts. The instincts and emotions, when organized around and conditioned by the dominant ideal, become integrated as sentiments.

“The unity of a harmonious personality is only gradually and imperfectly attained by the individual in the course of his growing up, his postnatal development; this is a development which takes place in the light of a multitude of experiences, of success and failure, of pleasure and pain, of satisfaction and painful frustration. Through such experiences the instinctive impulses become confirmed in certain directions, become fixated upon certain objects and in certain modes of seeking their goals; and at the same time they are turned away from other objects and other modes of expression. This is the formation of the sentiments, sentiments of love and hate, of liking and disliking, of respect and contempt, of admiration and fear, for various objects.

“Each sentiment is a higher integration; within one sentiment several instinctive dispositions may be integrated to form an harmoniously working system. But still the various sentiments thus formed are so many systems which may obstruct one another or conflict with one another. If a unitary personality is to be achieved, the various sentiments must be brought into one system within which their impulses shall be harmonized, each duly

subordinated to the higher integration of which it becomes a member. This higher integration is what we call 'character'; it is achieved by the development of a master sentiment which dominates the whole system of sentiments, subordinating their impulses to its own. . . .

"The only sentiment which can adequately fulfil the function of dominating and harmonizing all other sentiments is the sentiment of self-regard, taking the form of a self-conscious devotion to an ideal of character. . . . The integration of personality, the development of character, results from the formation of some dominant purpose, the adoption of some goal that is felt to be of supreme value, a purpose and a goal to which all others are subordinated as of less urgency and lower value. And of such master purposes, the one most truly and universally effective is the purpose of being an efficient and autonomous personality, a character capable of choosing and following whatever line of conduct reason may point to as the best."<sup>15</sup>

**Relative Dissociation as a Passive State.** In its passive state the mind is characterized by a relative dissociation. For example, a year ago I bought a tester for my radio battery. Just recently I needed to test my auto battery, and I bought another tester. Then suddenly I discovered that I already had one tester. I had known that fact all the time but I had not associated my knowledge with the demand of the new situation. The child mind is in a state of relative dissociation. Maturation means progressive integration. "A house divided against itself cannot stand,"—mental civil war is disastrous. When adjustment is especially difficult, the individual is apt to go to pieces, to get rattled, to be all broken up. Successful adaptation requires co-ordinated effort.

**Personality a Growing Thing.** Personality is a growing thing. The nervous system furnishes the physiological basis upon which mental systematization can be developed. "The normal action of mind is to make up from its components one unified personality."<sup>16</sup> The cerebral cortex, of course, is the center of

<sup>15</sup> McDougall, *op. cit.*, pp. 525-527.

<sup>16</sup> C. S. Sherrington, *The Integrative Action of the Nervous System*, p. 353. Scribner's, 1906.

nervous integration. Through a long period of training a mind is developed "in which the manifold impulses and mental processes are integrated for general purposive activity."<sup>17</sup> "The ego," as Ribot states, "is a coordination."<sup>18</sup> In Platonic terms, the aim of the virtuous man is to harmonize reason, spirit and appetite into a working whole. Justice, which is effective coordination, is thus materialized.

### Means of Integration

The older atomistic psychology tended to split the mind up into its several parts and to be content with decomposing the mental structure. The newer psychology is striving to put humpty-dumpty together again, to see the mind *in toto*: "Coordination puts emphasis on the parts united, integration on the whole which results from the integration of the parts."<sup>19</sup> The analytic approach is thus being discarded in favor of the synthetic view by modern psychology.

**The Task and Religion.** Integration may be through various channels. I shall mention only two. Mental organization is facilitated by absorption in a vital task which challenges one's powers and develops a sense of responsibility. If this task be self-assigned it becomes the focal point, the center of attraction to which the mind continues to return. When the task is undertaken as a part to be played in a cooperative venture, the sense of responsibility is correspondingly increased. Religion also is an effective organizer, harmonizing all one's conflicting desires into one single purpose, the achievement of the ideal of abundant life. Psychologically interpreted, the primary function of religion on its pragmatic side is integration.

### The Psychological Person—Reconciliation

In concluding the psychological concept of personality, one solution is given for reconciling the unity and multiplicity we find in the mind. The monistic view regards personality as the expression of a unitary indivisible agent capable of self-conscious

<sup>17</sup> Burnham, *op. cit.*, p. 38.

<sup>18</sup> T. A. Ribot, *The Diseases of Personality*, pp. 156-157. Open Court, 1895.

<sup>19</sup> Burnham, *op. cit.*, p. 32.

thinking and striving. Unity, however, is only an ideal which is approximated in the normal personality. The pluralistic view asserts that personality is the product of an integrative process by which a multitude of activities are coordinated in one har-

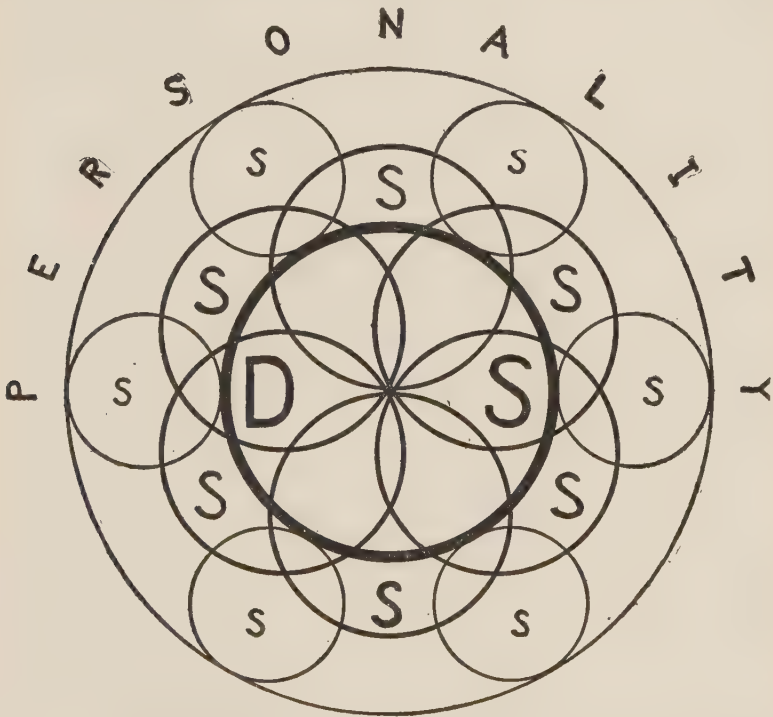


Figure 119. Diagrammatic Representation of the Monad Theory of Personality. A "person" represented as a complex of "selves," harmonized and unified under the domination of an idealized or "dominant self"—an impersonation of the socialized "I" which serves as a constituent unit in the psychical structure of social organization. S = Self; D S = Dominant Self.

monious system of activity. Multiplicity is best exemplified in the mental disorder known as multiple personality. A familiar illustration of this disorder from the realm of literature is the case of Dr. Jekyll and Mr. Hyde.

**The Monad Theory.** Both the monistic and pluralistic views of personality are true. Their reconciliation can be reached through a monad theory. Personality, from this standpoint, is

made up of a number of independent selves, or monads, which exist in their own right. Each monad is a thinking, striving self, endowed with the power of memory. The normal human personality is an integrated system of such monads, a hierarchy under the head of a supreme monad, an organization which under the rule of a dominating self becomes the socialized individual—the unit in a broadly integrated whole called society. It is the relation of the organized group of selves to the organized group of persons which becomes the subject matter of the chapter which follows—personality as conceived by the moralist and the publicist.

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J. B. Watson, *Psychology from the Standpoint of a Behaviorist* [N. Y.: Lippincott, 1919], Ch. XI, Personality and its disturbance, pp. 392-420.

R. S. Woodworth, *Psychology* [N. Y.: Holt, 1921], Ch. XXI, Personality, pp. 552-572.

2. What are some of the factors which enter into the popular use of the term?

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E. L. Thorndike, *Individuality* [N. Y.: Houghton Mifflin, 1911].

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7. Discuss personality in terms of being a good mixer.

Allport, see reference to question above.

8. How does the scientific differ from the popular conception of personality?

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9. Why are studies in abnormal psychology of value to a scientific understanding of normal personality?

S. Freud, *The Psychopathology of Everyday Life* [N. Y.: Macmillan, 1914], see especially the Introduction by A. A. Brill.

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11. Name three outstanding schools of psychological thought on the subject of personality.  
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J. R. Angell, "The Province of Functional Psychology," *Psychological Review*, Vol. XIV, 1907, pp. 61-91.
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17. Discuss the psychological conception of "person" as a bundle of selves.  
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19. Discuss the self-organization as a result of effort directed toward psychological order.  
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22. Discuss organization of the bundle of selves called personality in terms of the dominant self.  
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31. Discuss personality as a growing thing.  
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## CHAPTER XXIX

### MORAL AND LEGAL ASPECTS OF PERSONALITY \*

**Ethical and Jural Conceptions.** Upon the foregoing psychological background the ethical and legal conceptions of personality can be quite simply sketched and brought into perspective. We have been considering human nature from the viewpoint of that unique ability which marks off man from all other kinds of beings—the ability to organize. By this is meant his awareness of problems to be solved and his ability to invent ways and means of solving them.

**The Need for Taking Social Environment into Account.** When dealing with man's ability to organize, not only must the responses to stimuli of each individual organism be related to consciousness of purpose, and its drives be focused on ends to be achieved—not only must order be established and maintained in the multifarious ways which the mind of the individual has developed for thinking, feeling, and willing, but the very existence of the human organism depends on the ability of the many individuals who make up the community to think together, to feel together, and to will together. To this end each member of the community must develop group consciousness. Each group of persons must find a way of impressing on the individual a consciousness of need for harmonizing his acts with group ideals, group sentiments, and group will. Intelligent cooperation is possible only when the several dominant selves can function harmoniously; in no other way can the several motor mechanisms controlled by individual minds be brought into working relation. This means that each dominant self in each individual as a psychological person must be socialized; for harmony within the individual mind can be assured in no other way than through this method of control.

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\* By Professor Wayland F. Vaughan (see note at the head of Chapter XXVIII), and Professor Cleveland.

### **Group Consciousness Organized Around Common Ideals.**

The coordinating principle in the process of socialization is to be found in the ideals evolved through group experience as a guide to action. In a group of individuals whose dominant selves are organized around the same ideals, a bond of union is established through which all may be regimented for purposes of co-action—whenever the common welfare shall demand it. The compelling demand of each group is that each dominant self shall be brought into relation to each other dominant self—and where conflicts ensue that these be reconciled by group determination. This is a continuing challenge to human intelligence—to invent ways and means of organizing, subjectively and objectively, so that each person may be left psychically free as a self-determining person and at the same time the dominant self in each person shall be socialized by a common devotion to ideals acceptable to the group.

### **The Ethical Conception of Personality**

**The Need for Harmonizing a Community of Dominant Selves.** A further discussion of principles involved as a guide to judgment when adjustments are to be made to new situations need not be entered into here. Our interest now centers in the ethical concept of personality. The only principle directly pertinent is that the integration of the ideas, feelings, and wills of the several ideal selves to be socialized depends on the development of a common code of morality—the facts and factors of group approval and disapproval which become conventionalized as the moral order. It is only when individuals come to be conscious of an established moral order that the many dominant selves can be organized in a group personnel under leaders loyal to commonly accepted ideals—leaders who are responsive to the organized will of loyal and competent followers. This is to be accepted as the first premise for all reasoning about ethical personality. The ethics of organization must relate to a principle of loyalty—devotion to commonly accepted ideals; for individual judgment as to what is good or evil in choosing between alternatives presented, must have relation to that first essential to all thinking about problems of social adjustment—that mankind, to

live at all, must live cooperatively. A group ethic is necessary to human survival. The superiority of man as a self-conscious being depends on his ability to organize in such a manner that cooperation may be made intelligent. Human intelligence (at every point where adjustments are to be made that require deliberation) involves the exercise of moral judgment. The alternative is between the maintenance of a moral order and social demoralization. Moral judgment is in the last analysis a choice between survival and suicide. Moral order is to be conceived of as a way of thinking and feeling and willing which assures individual and group self-determination in harmony with the laws of nature and human nature. It is nature and the adaptations of human groups seeking to utilize its forces and resources that determine what the moral order shall be.

**The Moral Standard Evolved from the Totality of Experience.** The ethical conception of personality lays hold on this principle and applies it to the psychological conception of person; the application is made to and through that aspect of personality which has been referred to as the dominant self. This serves to bring all alternatives, all acts or proposed acts, to the bar of reflective reasoning whenever there is mental conflict—to the end that thinking, feeling, and willing, as well as acting, may be directed and determined by the sum total of experience, as distinguished from norms evolved for dealing with particular situations. In contemplation of the moralist, a “person” may exist as a psychological being without having any ethical existence at all. Moral judgment is the psychical force which socializes the dominant self—the socializing process beginning when consciousness of what is approved and disapproved by the group becomes a dominant motive. The ethical conception of personality is that of a human being who may be entrusted by associates with self-direction, and who may be held accountable for his actions. Moral consciousness is a growth. Moral judgment is a force which makes for character. Character is social.

**The Relation of Moral Judgment to Character.** Personality has three stages: first, one in which action is instinctive; second, a stage in which intelligent choices are made—when there is con-

sciousness of good and bad; third, a stage in which conduct, once consciously determined, becomes habitual—when character has been formed. An infant (one who has not had enough social experience to think in terms of social standards) would neither be moral nor immoral; it would be unmoral. A person who has been rendered unconscious by an anesthetic and who, while responding automatically to the surgeon's knife, has harmed himself or another would not be thought of as having committed a moral or immoral act; a person beside himself with a raging fever and who reacts in harmful ways would not be considered as moral or immoral—he is deranged. An insane person is not an ethical being although he may be conscious of selfhood and may have a psychological personality. The ethical content of personality is to be found in the actual or assumed ability of the individual to exercise moral judgment—discretion—in self-directed behavior.

**The Field of Ethics.** The broadest conception of what constitutes moral judgment is that described in the writings of John Dewey: "The foremost conclusion," he says, "is that morals have to do with all activity into which alternative possibilities enter. For wherever they enter a difference between better and worse arises. Reflection upon action means uncertainty and consequent need of decision as to which course is better. The better is the good; the best is not better than the good but is simply the discovered good." In this relation it is to be observed that "better" has reference to the alternatives present while "good" has reference to conduct. "Comparative and superlative degrees are only paths to the positive degree of action . . . actually then only deliberate action, conduct into which reflective choice enters, is distinctively moral, for only then does there enter the question of better and worse."<sup>1</sup>

**Elemental Factors of Ethical Personality.** The common notion is that ethics is concerned chiefly with the individual in his social relations—although it may extend to the conduct of a self-conscious, self-determining group in its relations to other groups. But in any event ethics has to do with the exercise of judgment about conduct, which has a social significance. When

<sup>1</sup> Dewey, *Human Nature and Conduct*, pp. 278, 279. Holt, 1922.

viewed from the standpoint of ethics, personality may be said to combine several elements among which are to be included the capacity for moral judgment. In the first place there must be incorporated into the ideal self a notion of right and wrong. Using the language of Dewey and Tufts, psychologically the process of socializing the individual "is one of building up a 'social' self. Imitation and suggestion, sympathy and affection, common purpose and common interest, are the aids in building such a self. As the various instincts, emotions, and purposes are more definitely organized into such a unit, it becomes possible to set off the interest of others against those interests that centre in my more individual good. Conscious egoism and altruism become possible."<sup>2</sup> Thus, the interests of self and others are raised to a plane of rights and justice.

**Moral Conception.** First be it observed, therefore, that we cannot think of ourselves save as social beings to some extent. The strengthening of social ties leads the individual to identify his feelings more and more with the good of others. Duty, like concepts of right and justice, is social in character, since everyone is in general related to others. "The conflict of desire and duty, of interest and principle, expresses itself as a conflict between tendencies which have got organized into one's *fixed character* and which, therefore, appeal to him (the individual) just as he is; and those tendencies which relate to the development of a larger self, a self which should take fuller account of social relations."<sup>3</sup> The individual reads his duty in the judgments of his fellows, in the customs and codes of honor, and in the religious precepts of the gods, finding in gods and laws, in custom and authority, the true rational law of life. This law, as it is impressed upon his consciousness and is incorporated into the thinking of his dominant or ideal self, becomes *his* law. The individual thus recognizes himself as a social being and as such becomes conscious of "duty." What is made binding upon him or is necessary, takes its place in a definite moral conception. The ethical man then has learned how to adjust himself to the demands of the social code in matters of conduct.

<sup>2</sup> Dewey and Tufts, *Ethics*, pp. 11-12. Holt, 1913.

<sup>3</sup> *Ibid.*, p. 346.

**Moral Sentiments—Conscience.** A second element which enters into the ethical conception of personality is that a moral being must have a conscience—he must have developed not only moral perception but moral feelings as well. Conscience operates as an imperative drive to choose the right rather than the wrong as a personal mode of conduct. Schopenhauer gave us the first thorough analysis of conscience.<sup>4</sup> Here we may cite only a few of the elements. There is the fear of criticism and of punishment, which may be so far-seeing as to anticipate the tortures of hell, in time to avoid disgrace on the day of judgment. There is the desire for the esteem of others and for the esteem of self which we call self-respect. The parental smile guides the growing child in its search of correct conduct. There is the wish that others treat us fairly and coincident with this, the belief that the best way to secure favorable treatment is to live righteously ourselves. There is political sentiment which prompts us to loyal citizenship. There is the joyous pride that swells with the consciousness of moral integrity. There is the perception of social advantage which may be gained by a policy of honesty. The individual learns by experience what the consequences are which issue upon the expression of his various tendencies. He learns to discriminate the helpful from the harmful modes of behavior. He makes his inclinations conform to the dictates of duty. And finally, there is the dread of mental conflict and the painfulness of conative strife. The censor within thus warns us of the dangers of immorality and urges us to follow the dictates of the “still, small voice that bids us do the right.”

**Moral Responsibility.** Thirdly, the ethical individual is assumed to be free and therefore is responsible for his acts. He is capable of distinguishing between right and wrong, of exercising discretion in choosing his line of conduct. Since man can, within limits, make voluntary choices and since he is conscious of what he is expected to do, he can be held responsible for his behavior. The awareness of the individual that he is morally responsible is an important factor in the development of the

<sup>4</sup> A. Schopenhauer, *The Basis of Morality*. Allen and Unwin, 2nd ed., 1915.

ideal self. Moral responsibility must be included in the ethical conception of personality.

### **The Achievement of Unity of Selves in the Moral Order.**

A fourth aspect in the ethical conception is the achievement of moral unity. As we have seen, there are elements within the mind which inevitably come into conflict. From the ethical point of view, man has a dual constitution; he is a creature both of sense and of inspiration; he has a carnal and an ideal nature; he possesses a lower self and a higher self. Man's impulses seek selfish gratification but reflection commands the inclinations of the moment to come to account before the tribunal of reason. The human being is both appetitive and rational. Reason is just as insistent as is appetite.

**Exercise of Control Through the Will.** Unification and systematization of interests and purposes are essential to the formation of an ethically sound personality. "A man's moral unity is manifested by a constant striving to realize a definite system of ethical purposes, and any habitual and systematic departure from the broad lines of conduct consistent with this end, any persistent pursuit of interests which are incompatible with its realization, implies a doubling of personality which is as real and as important as any of the conditions to which this term is usually applied. . . . Our bodily appetites urge us in one direction, our ideas of right and wrong and our feeling of 'ought' urge us in another. If sometimes we follow one course and sometimes the other, two systems of opposed conative dispositions become organized by habit, each of which, throughout life, struggles for the mastery of the whole personality."<sup>5</sup> Moral unity can be brought about only by directing attention to integration as an objective.

**Emergence of Moral Unification—Character.** The attainment of moral unification results in character. Character may be defined as "the predominating tendency of the personality traits."<sup>6</sup> Dewey defines character as the interpenetration of habits; they are habits which have a social significance. As Aristotle pointed out,

<sup>5</sup> T. W. Mitchell, quoted by W. McDougall, in *Outline of Abnormal Psychology*, p. 528. Scribner's, 1926.

<sup>6</sup> M. Prince, "The Structure and Dynamic Elements of Human Personality," *Journal of Abnormal and Social Psychology*, Vol. XV, 1920, pp. 403-413.

virtue is a definite habit of mind and ethical unity is not reached till right doing becomes so habitual as to be automatic. Habits build character—and the habit which is of the utmost importance in the quest of effective unity is the habit of integration, the mode of living that ever aims to harmonize the various conflicting impulses into a systematic whole. Integration of the ethical personality can be achieved through objective devotion to the whole of things—and the whole of things includes society. Just as the mother realizes her fullest self in thinking not about her own needs but about those of her child, so men can reach ethical completion by wholehearted devotion to an ideal which may be impersonated as God or revered as the Universal Good. Moral judgment always calls for the subordination of the lesser to the larger good—around which the sentiment of loyalty is organized, and the feeling tone of which manifests itself in conscience. The habitual responses to the socialized impulses constitute character.

### Legal Conception of Personality

**The Need for an Institutional or Legal Order.** The problem of organization is one not only of organizing human nature but also of organizing human beings and directing and controlling the action systems of communities. Human nature, when organized, is brought under the control of intelligence. Thus, as has been said, organization begins with self; the bundle of selves is socialized as the ethical person; the individual is made conscious of a moral order. Both the psychological and the moral order, however, must be conceived of by intelligent beings as thinking beings. And thought is a process by which all the mental powers are focused on an object or objective which comes to occupy the centre of attention. When considering organization, scientific analysis has to do with the mechanisms and processes of control. All reflective reasoning about the control-mechanisms must have relation to that which is to be controlled. Cooperation (and this is the end and aim of both the psychological and moral order) depends on the organization of a group action system. This must be evolved by the group. The regimentation of the several individual motor-mechanisms can be brought about only by estab-

lishing rules of action that are enforced by the group. This means the establishment of an institutional or legal order.

**Distinction Drawn Between Moral and Legal Order.** The first and most fundamental conception of legal order is to be found in "the legal person." What is meant by legal person has been the subject of profound philosophic discussion as well as judicial opinion. The purpose has been to clearly identify moral judgment with awareness of a moral order and legal judgment with requirements of law. A legal person, however, is assumed to be capable of distinguishing right from wrong. Recognizing the fundamental importance of the distinction, Willoughby in his "Fundamental Concepts of Public Law" has this to say: "It is unfortunate that the word Person as a technical term should have found lodgement in jurisprudence for the idea connoted by it is quite distinct from the meaning attached to it by the moralist and psychologist. This difference not being steadily kept in mind confusion of thought has resulted." This is Willoughby's conception of an ethical person: a living being, with reflective powers, capable of self-consciousness (that is, of conceiving of itself as an entity with interests and desires of its own and with a continuous individuality distinct from that of other similar beings), of being able to exercise a will and therefore able to determine its conduct according to deliberative judgment, to appreciate distinctions between good and evil, and, as a result, to feel or have imputed to it a moral responsibility for all such acts as are within its own control.

**The Basis for Legal Judgment.** While the psychological and ethical conception of the person ("a being capable of reflection, judgment, and of volition and to whom moral responsibility may be imputed") is held to be fundamental, yet it is something quite separate and distinct from the conception of the jurist. This conception is approached by the last named author in the following manner: To the jurist a law states a rule of conduct which imposes legal obligations on individuals and—as guaranteeing conduct on the part of other individuals or the State itself which the State through its political power will enforce—endows them with legal rights. In other words, the conception of the publicist and

the jurist resembles the conception of the psychologist in that it is true to the monad theory; it resembles the conception of the moralist in that both are inventions, fictions of the mind; the two conceptions differ in that the first relates to something which is objective—a group action system. Legal personality is mechanistic in that it correlates will with action. As such, the legal person is the constituent unit in every scheme of social organization—such schemes being objective to the dominant person. Legal personality is the bridge between the moral group-conscious individual and the several associations into which the individual enters. Whenever consideration is given to any question of legal rights, it is the juristic person with which we have to deal.

#### **When Legal Order Is Not Consistent with Moral Order.**

So long as the law remains unchanged, it determines what powers may be exercised and by whom—whether the powers, rights, duties, and actions authorized or enforced are approved by the conscience and moral judgment or not. The test of all legal judgments is: the legality of a relation under consideration; does it establish a right or duty; can it be enforced? The significance of the juristic person is to be found in the institutional order which determines whether rights accrue and duties are imposed. Only juristic persons can enter into associate relations which carry with them rights and duties that are enforceable by the coercive machinery of the community. By placing the machinery of organized society back of the instituted order, definite rules of procedure are laid down by which a morally responsible person can be converted into an active agent as a dominant personality. Thereby the community determines what “person” has the right to dominate the agencies and instrumentalities through which the various individuals and groups of organized society achieve their ends. The legal person is one who has the qualifications prescribed by law for entering into contracts and for acting as an agent of the community or group.

**Application of Legal Personality to Artificial Beings.** Because in contemplation of law all rights and powers are personal, every group or association which is assumed to have rights is conceived of as an artificial being. A natural person enjoying

the right to property, for example, dies—his legal personality ceases; but personality is thereupon ascribed to his estate—that is, under the rules established to govern the conduct of human affairs in the community, the estate is assumed to have definite rights and to have imposed upon it duties which are enforceable. In this latter case the fiction of legal personality is made real by providing artificially the instrumentality, called an executor or administrator, through which the estate can think and feel and will and act. And any and every manner of thing and combination of things or group of persons whose existence is assumed to be for the common welfare may be impersonated artificially. Monuments, trees, families, copartnerships, corporations, communities, the State—all may and do have attributed to them legal personalities and these come to be the chief means of integrating, coordinating, elaborating, and enlarging both individual and social organization.

### Other Conceptions of Personality

Three very definite conceptions of personality have been discussed—the psychological, the ethical, and the legal. Each of these is progressive in its development—different aspects of mental organization. There are other conceptions which should be brought into perspective. In the literature of the social sciences we find such phrases as “the economic man,” “the philanthropic person,” “the executive mind,” “the judicial-minded person.” These call attention to different types of dominant self, or different sets to character which play an important part in appraisals of personalities adapted to leadership when selections are to be made on the basis of qualifications; or when persons in responsible or exalted positions are criticized for their acts. The economic person is a conception fundamental to thinking in terms of an established economic order. The moralist is a personality evaluated in terms of the moral order. The philanthropist gains his distinction from characteristic responses to humanistic interests, as these take form in a social group or community or in group consciousness organized around ideals of social justice. The many questions of adjustments in the interest of social justice have led to several

specialized fields of scientific inquiry such as philanthropy, poverty, dependence, delinquency. All of these, in fact every one of the several sciences, may be thought of as a literature dealing with the individual as a human being.

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22. What is the philosophic conception of personality?

23. How are the several conceptions of personality related to specialization in studies of human nature?

## CHAPTER XXX

### PROPERTY—AN OBJECTIVE ASPECT OF PERSONALITY \*

#### Relation of Mind to Matter

**The Line Drawn in Conscious Experience Between Self and Non-Self.** Any attempt to define legal personality (to conceive of a person as a possessor of enforceable rights) must have reference to that which is objective to the mind. The mind serves as the directing, controlling agent. It is the pilot. Mind functions through mechanism; it expresses itself in terms of interests, objectives, ideals. Mind thinks and feels, is conscious of wants, has desires. Mind wills action. Rights are attributed to, and duties are imposed on persons by a community of minds. Rights and duties have reference to relations established, or to be established, between mind and matter. These relations are legalized; they are instituted between thinking, willing beings and the material instrumentalities in which and through which intelligence expresses itself. By processes of psychological analysis we are carried back to the fact of consciousness—the ability which the thinking, feeling, willing being has, to draw a line (subjectively and objectively) between self and non-self.

**Legal Personality Created by Entering into Relations Between Self and Non-Self.** We also must face the fact when seeking to think incisively about the legal conception of personality that there can be no such thing as legal personality except on the basis of relations actually entered into—relations which under existing law have the effect of establishing rights. Another way of stating the same conclusion is this: rights accrue from decisions made by psychological and moral persons concerning relations entered into or to be entered into in which conclusion is reached as to who, under the law or rules laid down for the government

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of conduct in the community, shall have the right to dominate—and also who shall be bound to respect this right of domination. Personality as socialized individuality is made effective as directing agent by being clothed with rights and by having duties imposed on it.

**All Rights Based on an Exercise of Will.** All rights and all duties, in other words, are based on consent. In an autocratic régime this consent may have been won by force, and submission may have been the alternative of death or cruel punishment; but in a democratic régime consent must be voluntary. The consent given by each to any arrangement out of which rights and duties proceed must be made after taking into consideration all of the alternatives and opportunities. Consent, therefore, must be based on good or valuable consideration. In all transactions among legal persons, consent must be between persons who have arrived at the age of discretion and are competent to do business, and must take the form of contract or compact. This is assumed to be the only means of effecting a reconciliation of conflicting interests in a democracy—in theory at least.

**In Democracy Rights and Duties Rest on Good-Will and Loyalty to Ideals.** No right or duty can accrue except in circumstances such as insure the good-will and loyalty of everyone concerned. The doctrine of social compact and the integrity of the freedom of the individual secured by the law—these are underlying assumptions in all modern political philosophy, the working hypotheses of all *a posteriori* reasoning as well. Such doctrine lies at the foundation of both substantive rights and remedial procedures, including the procedures of courts of law and equity. Because rights and duties accrue only when legally approved relations are entered into, judicial tribunals cannot determine what the rights and duties of persons are except after decisions have been made or actions taken; no opinion or judgment can issue except on a bonafide or actual case.

**Property the Objective Aspect of Rights and Duties.** Until relations are entered into by psychologically and morally conceived persons who have qualifications prescribed by law, no such being as a legal person can exist; and when such a person comes into

existence, by this very act of creation, an objective something is also created which, as distinguished from the person, is a thing—but which in terms of law, so far as it relates to rights and duties, is property. Things, therefore, may be considered as the objective aspect of personality. Property is to be regarded as the legal aspect of the thing, growing out of the fact that a relation entered into between persons and things (property) is that over which the person has the right to exercise dominion.

**Property a Factor in the Development of Personality.** By ethical analysis we draw the line between the moral and the non-moral. By legal analysis we draw the line between the person who dominates and the thing which is dominated. Therefore, a moral person (an individual who has the capacity for the exercise of moral judgment) may be a thing. Such is the status of a slave who is entrusted with the exercise of judgment in the case of his master's estate, even with the duty of training his children. A relationship has been entered into between master and slave which gives to the master the right to exercise complete domination over another individual who consents to an arrangement in which he is dominated; the slave consents to being a thing. The same is true of any contract of service. The one who consents to an arrangement in which he is the serf is for that purpose a thing, the right to domination by another having been consented to in an arrangement which is enforceable by the coercive machinery of the community. Thus, every individual member of a community has his "thingality" as well as his personality; and in addition, all of the impersonal or non-human resources of a community are to be thought of in terms of means to end—as things.

### Persons and Things

**Conceptions of Jurist and Publicist.** Pollock, who is considered one of the outstanding writers on jurisprudence, has defined a thing as "the object of a right," that is, whatever is treated by the law as the object over which one person exercises a right, and "with reference to which another person lies under a duty." This presents the two legal aspects of personality—the right to dominate, and the duty to submit; but it also clearly dis-

tinguishes between the concepts, "persons" and "things." The thingality of an individual is just as separate and distinct from his personality as is the non-human from the human. The conception becomes very clear at the time of death; then personality ceases but thingality continues. The body is still a thing; it is still the object of a right or rights. A further fact of interest is that whereas the estate of the deceased person was a thing before his death, now it has personality attributed to it as well.

**Abilities and Services as Things.** The abilities which one possesses are things in the sense of being the objects over which one exercises a right and with reference to which another lies under a duty. In this sense, abilities are "commodities"; but under our law the sale of one's ability for a definite time or purpose does not in any manner affect his personality. The person is still there—as the possessor of ability, one who is under duty or obligation to serve—quite as fully as is the person who has the right to dominate, and control the use of this service. And so Pollock, with cogent reasoning, states the conclusion that, "A thing is, in law, some possible matter of rights and duties conceived as a whole and apart from all others, just as, in the world of common experience, whatever can be separately perceived is a thing."

**The Essential Fact About Property.** Making use of this idea, Willoughby in his "Fundamental Concepts of Public Law" calls attention to the fact that a thing may be "corporeal or incorporeal, tangible or intangible; but it is always, in the eyes of the law, something which can be brought into relation with Persons, that is, of interest to them in some way, and these interests, as defined and protected by law, provide the substantial basis for the rights and duties which these persons possess or have laid upon them. Thus, the human individual who is a person in the psychological or ethical sense, and who, in other respects, may also be treated by the law as a legal person, may, at the same time, be treated as a thing when brought into relation with legal persons." He then cites the slave so far as he is treated as property; the serf so far as he is bound to serve his superior; the wife, the child, or the apprentice so far as they are made subject to the domination of husband, parent, or master.

**Rights and Duties Conceptions Which Relate to the Domination of Things.** The point of view here taken is that property is an extension of personality into the environment; that property, like personality, is one of the fundamental inventions of the human mind; that property must take place alongside of the conception of personality; that it is in fact an invention necessary in order that intelligent beings may enter into cooperative relations when dealing with environment; that property and personality are twin-born and complementary in any scheme of social organization which has achievement for its purpose. All this becomes a part of the rational basis of that great

### BLACKSTONE'S CLASSIFIED RIGHTS

#### I. RIGHTS OF PERSONS; which are

- I. NATURAL PERSONS; whose rights are
  - 1. *Absolute*; viz., the enjoyment of
    - 1. Personal security
    - 2. Personal liberty
    - 3. Private property
  - 2. *Relative*; as they stand in relations
    - 1. Public; as
      - 1. Magistrates; who are
        - 1. Supreme:
          - 1. Legislative
          - 2. Executive, viz., the king, wherein of his
            - 1. Title
            - 2. Royal family
            - 3. Councils
            - 4. Duties
            - 5. Prerogative
            - 6. Revenue
              - 1. Ordinary; viz.
                - 1. Ecclesiastical
                - 2. Temporal
              - 2. Extraordinary
        - 2. Subordinate
      - 2. People; who are
        - 1. Aliens
        - 2. Natives; who are
          - 1. Clergy
          - 2. Laity; who are in a state
            - 1. Civil
            - 2. Military
            - 3. Maritime
    - 2. Private; as
      - 1. Master and servant
      - 2. Husband and wife
      - 3. Parent and child
      - 4. Guardian and ward
- 2. BODIES-POLITIC, OR CORPORATIONS [ARTIFICIAL PERSONS].

#### II. THE RIGHTS OF THINGS (PROPERTY).

literature and broad field of scientific inquiry called jurisprudence. The science and profession of law deals with rights and duties. No one has more broadly treated the subject than Blackstone in the volumes which constitute his "Commentaries." To make this point clear it is necessary only to read his outline of rights which gives the key to all the material contained in that voluminous text.

**Importance Assigned to Property by Blackstone.** From the outline as shown, it will be seen that Blackstone divides rights into two classes: rights of persons and rights of things—but what he means by rights of things is, in fact, the rights of persons who dominate things. To make clear his meaning we quote the following which is introductory to the volume dealing with things:

"The former book of these Commentaries having treated at large of the *jura personarum*, or such rights and duties as are annexed to the persons of men, the objects of our inquiry in this second book will be the *jura rerum* or those rights which a man may acquire in and to such external things as are unconnected with his person. These are what the writers on natural law style the rights of dominion, or property. . . ."

Not only do these objective "things" with which man must deal and with respect to which definite relations are entered into, having in mind their domination—not only do these "things" constitute the subject matter of law, the objective aspects of the rights of legal persons, but they hold quite as important a place in organizing the minds of individuals and in developing notions of self and non-self. The idea of property is fundamental to the development of the psychological and the moral as well as the legal concepts with which we have to deal. On this point Blackstone has to say, "There is nothing which so generally strikes the imagination, and engages the affections of mankind, as the right of property; or that sole and despotic dominion which one man claims and exercises over the external things of the world, in total exclusion of the right of any other individual in the universe."

**Kent's Classification of Rights and Duties.** Kent who, as a later commentator on American law, holds a place of honor and

authority equal to that of Blackstone as a writer on the English common law, follows much the same general outline for the purpose of discussing rights and duties. He, however, in his introductory and first volume places greater stress on the relations entered into which give rise to these rights. His first chapter deals with international relations. He then takes up the relations of government—national, state, and local. Following these more general relations, he takes up the associations entered into by persons and treats them from the viewpoint of rights under natural law, such as those rights which are guaranteed under bills of rights as common to all men; following this, he discusses those rights which grow out of relations which are subject to regulative law, such as domestic relations, industrial relations, commercial relations, etc. Under the law of persons he uses much the same classification as is used by Blackstone except that it is adapted to American as distinguished from English conditions. Rights and duties, so far as they have to do with non-human relations, however, (or relations of persons to non-human things) follow very closely the outline or classification that has come down to us through the customs of trade and barter and the institutions of feudalism—the accepted rights of personal property and of real property.

**Kinds of Property.** Property is discussed as that which is in the nature of human inventions or conventions, and that which relates to “the soil”—the gift of God. These two classes are called “personal property” and “real property.” Personal property is something which is not fixed to the soil. Personal property rights are to be thought of in terms of chattels—real chattels, personal joint chattels, rights of action, etc.; and the right or title to such chattels is thought of as obtained by original acquisition, transfer, gift, bailment, agency, etc. Rights to real property are labeled in various ways to indicate the kind of use, such as: riparian rights; highway servitude, and vicinage; party walls; division fences; running water; etc. These categories of rights are mentioned simply as indicating some of the refinements into which it has been necessary to go in the regulation of relations which may be entered into, and which must be entered into before any rights at all accrue. When these regulations are entered into,

however, the person to whom the right accrues has a clearly marked out jurisdiction in which he may dominate—in which his dominant self may function. And by these very rules of procedure, communities undertake to determine what shall be the dominant selves of the psychological and moral persons who may direct the affairs of a community in organization for cooperative achievement.

**The Law of Property Rests on Will.** The law of property, therefore, as well as the law of persons, may be thought of as the rules set up by a community to determine how each individual (possessed of the right of initiative) is guaranteed freedom of choice, is held responsible for actions—and how any two or more such individuals may organize for the purpose of achieving socially approved objectives. The resulting rights and duties are incidents accompanying relations voluntarily entered into. Thereby are determined the ways in which individuals may function when seeking to realize willed purposes. In a democratic régime the manner of establishing rules governing conduct—of enforcing rights and duties, of determining what agencies shall be employed for rendering service—is left to the free determination of individuals who constitute the constituent personnel of the community. Because each of these persons seeks self-expression in ways that are approved, the arrangements entered into are enforced—the social purpose being that all may work together for the achievement of ends assumed to be for the common welfare, thereby assuring that rights exercised and duties imposed shall rest on good-will.

### Social Justification of Private Property

**Property a Device for Making Dominant Personality Effective.** From the foregoing it appears that the institution of property is a device adopted by a community for making leadership (that is, dominant personality) effective. In the exercise of the right of self-expression, the individual members of a community enter into such relations that they may achieve their willed purpose. The institutional order constitutes a program of social regulation by means of which the will of the community—as this

comes to be expressed through governing agents, is impressed on the individual. These institutions, therefore, determine to whom shall be given the right to dominate in each group relation and group activity. Because property is the objective aspect of rights and duties, the law of property determines who shall own and control the instrumentalities of self-expression in group achievement. Property is a creature of group will. Property has no existence apart from group will. Property is created by the group. The right of property depends on the group—both for its existence and its enforcement. Property, therefore, must be considered in the nature of a trust—to be exercised for the benefit of those who (out of consideration of public policy) are made the beneficiaries of the institution; and the administration of private property must always be subject to the will of the community as this comes to express itself when considering problems of social adjustment.

**All Wealth in the Nature of a Trust.** The idea of trusteeship is as old as the idea of property itself. We find the idea of trusteeship set forth in Holy Writ. We find the trust idea written in the Roman law. It is an integral part of our modern conceptions of social justice. Andrew Carnegie, at a time when he was considered the wealthiest man in the world, still adhered to the notion that property was to be considered as a trust and that the institution of property was to be thought of as rules governing the administration of this trust.

**Mr. Carnegie's View.** "We start," said Mr. Carnegie, speaking of the capitalistic régime in a series of articles published in the *North American Review*,<sup>1</sup> "with the condition of affairs under which the best interests of the race are promoted, but which inevitably gives wealth to the few. Thus far, accepting conditions as they exist, the situation can be surveyed and pronounced good. . . . It will be understood that fortunes [wealth] . . . are . . . not moderate sums saved by many years of effort, the returns from which are required for the comfortable maintenance and education of families. This is not wealth but only competence which it should be the aim of all to acquire, and which it is for the best interest of society should be acquired." What Mr. Car-

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<sup>1</sup> "The Gospel of Wealth," *North American Review*, June and December, 1889.

negie calls "surplus wealth" is the subject-matter of his essays; and this he characterizes as a trust to be administered for the benefit of the community. But with equal force he might have included the amounts needed to meet the social obligations of the owner of a home or the possessor of a small income. The reasons given by Mr. Carnegie for his conclusion, that wealth should be administered as a trust, are social reasons. In the first place, he points out that it would be for the benefit of the possessors of wealth and their families—since there is no surer way of ruining a family than by leaving it a great fortune, because this only offers inducement to idleness and unsocial emulation. Furthermore, such a use or disposition is said to be at variance with the social purpose of property—the making of useful personality effective within the community.

**Views of Writers on Social Ethics.** The same point of view is presented by many writers—not only those who have been keen observers in the field of practical affairs but also those who have won distinction and authority as moralists and social scientists. Mecklin, for example, makes this statement of the case:<sup>2</sup>

"A right is simply a way of acting, of developing capacities or of exercising functions, that is sanctioned by the moral sentiment of the community. The basis of all rights, therefore, including that of private property, is found in the constraining sense of well-being that is common to all the members of the group among whom the right is exercised. The distinction of 'mine' and 'thine' depends not so much upon occupation as upon a feeling of common interest that is furthered and made articulate by this distinction. The idea of property in so far as it has any ethical element, therefore, and is not measured in terms of the good old rule that he shall take who has the power and he shall keep who can, presupposes this feeling of common interest. Society assures to each of its members in the right of private property the power to secure and exercise the means necessary for the expansion of personality and the development of capacity as moral creatures. The general will that provides the sanction for the right must also determine the scope and purpose of the right. It must be exercised in the interest of the social good.

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<sup>2</sup> *Introduction to Social Ethics*, pp. 302, 303. Harcourt, 1921.

"The fact that property is primarily a social trust conditions fundamentally the ethical implications of property. For to exercise the right of property as a social trust forces the individual to reflect upon the bearing of its exercise upon the welfare of the community as a whole. There arises a constant need for correlating the laws that govern the right of property and the human values it is designed to serve."

Speaking of the need for the recognition of the social point of view as distinguished from the autocratic notion which was held to at a time when all institutions were dominated by exploitive classes, Mecklin goes on to say, "The institution of private property must be emancipated from the moribund legal abstractions of the eighteenth century. . . . There is no surer way in which to discredit private property than to seek its justification in eighteenth century philosophy or even in the arbitrary deliverances of courts and the rubrics of the law. These are of value only in so far as they enjoy the moral sanction of the community. . . . The real safeguard of private property, therefore, is not to be found in the provisions of the Constitution nor in the judicial interpretations of that great document by learned judges, but in a sane and intelligent adaptation of the institution to the needs of the community. The real menace to private property arises from all arbitrary and unintelligent use of it contrary to the demands of society as a whole."

**Sanction Given to the Institution of Property by Our Political Constitutions.** If one thinks of property in terms of social values, and especially of its relation to personality, the important place assigned to this institution in constitutional law should not excite either hostility or jealousy. The right to acquire property and to be protected in its proper uses is just as sacred and fundamental as is the right to personal liberty. Both of these are considered as natural rights in all of the fundamental documents in which expression is given to the philosophy of democracy. Few of our constitutions contain a declaration of what the underlying promises are that guided the thought of the time in which these fundamental documents were promulgated. However, the constitutions of Massachusetts and Virginia contain such declarations. Article I of "the declaration of rights" formulated and approved

by citizens of Massachusetts is as follows: "All men are born free and equal, and have certain natural, essential, and unalienable rights; among which may be reckoned the right of enjoying and defending their lives and liberties; that of acquiring, possessing, and protecting property; in fine, that of seeking and obtaining their safety and happiness." This is but a succinct statement of the philosophy of natural rights in which are formulated the conceptions of right and wrong, and out of which emerged those institutions which govern the living arrangements of the modern world. In this, the institution of property is considered quite as fundamental as the right to life and liberty; but the very declaration from which the above article is quoted also sets up the notion that both the rights of personality and property must be exercised as trusts—no other conclusion can be drawn from that historic formula. Perhaps the best statement of the principle is the one which follows in Articles VI and VII: "No man, nor corporation, or association of men, have any other title to obtain advantages, or particular and exclusive privileges, distinct from those of the community, than what arises from the consideration of services rendered to the public; . . . Government is instituted for the common good; for the protection, safety, prosperity, and happiness of the people; and not for the profit, honor, or private interest of any one man, family, or class of men."

From this brief and general consideration of the institution of property, we turn to the consideration of the means used for regimenting the personal and non-personal resources of community life for common welfare ends.

### QUESTIONNAIRE WITH READING REFERENCES

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W. W. Hyde, *The Five Great Philosophies of Life* [N. Y.: Macmillan, 1922], The need of instruments, pp. 191-194.

R. H. Tawney, *The Acquisitive Society* [N. Y.: Harcourt, 1920], Ch. V, Property and creative work, pp. 52-83.

2. In what sense is property the objective aspect of personality?

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### 3. Why is property a factor in developing personality?

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 W. Rauschenbusch, *Christianizing the Social Order* [N. Y.: Macmillan, 1912], pp. 341-47.  
 L. T. Hobhouse, *et al.*, *Property* [London: Macmillan, 1913], Ch. III, Principle of private property, by Lindsay, pp. 65-81; Ch. VII, Property and personality, by Holland, pp. 169-192.  
 H. S. Coffin, *A More Christian Industrial Order* [N. Y.: Macmillan, 1920], pp. 33-35.

### 4. How are "persons" and "things" distinguished in law?

- F. Pollock, *A First Book of Jurisprudence* [London: Macmillan, 1923, 5th ed.], Pt. I, Ch. V, Persons, pp. 111-129; Ch. VI, Things, events, and acts, pp. 130-171; Ch. VII, Relation of persons to things, pp. 172-207.  
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 J. Austin, *Lectures on Jurisprudence* [London: Murray, 1879, 4th ed. rev. 2 vols.], Vol. I, pp. 367-391.  
 T. C. Sandars, *The Institutes of Justinian* [London: Longmans, Green, 1869, 4th ed.], Persons, pp. 28ff.; Things, pp. 37ff.  
 Ortolan's *History of Roman Law* [London: Butterworth, 1871, Prichard and Nasmith trans.], pp. 567ff., 608ff.

### 5. In what sense are personal abilities and services "things"—"commodities"?

- Ely, *Op. cit.*, Vol. II, Pt. II, Ch. VI, Contracts for personal services with special reference to the labour contract, pp. 627-642; Pt. IV, Appendix II, pp. 795-821.  
 J. Locke, *Two Treatises on Civil Government* [London: Routledge, 1884], Bk. II, Ch. V, Of property, pp. 203-216.

### 6. What is the essential fact about property?

- W. Blackstone, *Commentaries on the Laws of England* [Philadelphia: Lippincott, 1910, 2 vols.], Bk. II, Ch. I, pp. 2-15.  
 Sandars, *op. cit.*, Rights over things, pp. 43ff.  
 Hobhouse, *et al.*, *op. cit.*, pp. 6-8.  
 Pollock, *op. cit.*, Pt. I, Ch. VII, Relations of persons to things, pp. 172-207; Ch. VIII, Claims of persons on persons, pp. 208-228.

### 7. Why must all rights and duties be defined in terms of persons and things?

- Pollock, *op. cit.*, Pt. I, Ch. II, Justice according to law, pp. 30-56; Ch. III, Subject-matter of law, pp. 57-83; Ch. IV, Divisions of law, pp. 84-110.  
 Austin, *op. cit.*, Vol. I, pp. 353-366.

### 8. How does Blackstone, in his "Commentaries," classify rights and duties?

- Blackstone, *op. cit.*, see outline of Contents, Vol. I; also Bk. I, Ch. I, pp. 122-125.

### 9. What is the importance assigned to property by Blackstone in discussion of personality?

- Blackstone, *op. cit.*, Vol. I, Bk. I, Ch. I, pp. 129-141.

### 10. How does Kent, in his Commentaries, classify American law?

- J. Kent, *Commentaries on American Law* [Boston: Little, Brown, 1873, 4 vols., 12th ed.], see outline of chapters.

### 11. What is Kent's classification of property?

- Kent, *op. cit.*, see outline of chapters for Vol. II.

### 12. What is the relation of the right to property and contract to the maintenance of a social order based on good will?

- W. J. Kerby, "The Moral Diagnosis," *Annals of the American Academy*, Vol. III, Sept. 1922, pp. 1-7; H. S. Dennison, "An Employer's View of Property," pp.

58-59; S. A. Lewisohn, "The Employers' Responsibility to the Community," pp. 65-69.

Coffin, *op. cit.*, Ch. V, The Christian as employer and employee, pp. 59-74.

13. Why is it necessary to consider private property as a trust to be administered for the welfare of the community?

Ely, *op. cit.*, Vol. I, Bk. I, Pt. I, Ch. VI, Social theory of private property; or private property a social trust, pp. 165-199.

Hobhouse, *et al.*, *op. cit.*, Introduction, by Gore, pp. VII-XX; Ch. IV, Biblical and early Christian idea of property by Bartlet, pp. 83-116.

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Coffin, *op. cit.*, Ch. III, The Christian as owner, pp. 31-44.

14. What is the viewpoint of Andrew Carnegie as stated in his "Gospel of Wealth"?

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15. What is the ethical view of the social justification of private property?

A. A. Bruce, *Property and Society* [Chicago: McClurg, 1916], Ch. I, Legal and social concept of property, pp. 1-13; Ch. III, Necessity of extended private ownership to national greatness, pp. 26-38.

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A. T. Hadley, *Conflict Between Liberty and Equality* [N. Y.: Houghton Mifflin, 1925], Ch. II, Uses and dangers of property right, pp. 48-95.

F. A. Cleveland and J. Schafer, eds., *Democracy in Reconstruction* [N. Y.: Houghton Mifflin, 1919], Ch. IV, Democracy and private property, by Kelsey, pp. 69-95.

D. G. Ritchie, *Natural Rights* [London: Sonnenschein, 1895], Ch. XIII, Right of property, pp. 263-271.

H. Cox, *Economic Liberty* [Longmans, Green, 1920], Ch. II, Ethics of property, pp. 21-25.

Hobhouse, *et al.*, *op. cit.*, Ch. II, Philosophical theory of property, by Rashdall, pp. 33-64.

L. Abbott, *The Rights of Man* [London: Clarke, 1901], pp. 108-114.

16. What is the principle laid down in our political constitutions?

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## CHAPTER XXXI

### SOCIAL ORGANIZATION \*

**Complexity of the Subject.** One who undertakes the task of bringing this subject of social organization into scientific perspective is confronted by a difficulty which is well-nigh insurmountable. Social organization is as inclusive as life; it covers the whole range of human experience. Society is the most complex idea that the mind has ever conceived. Human society may be set off as being quite separate and distinct from other collaborating arrangements. Sub-human cooperation is essentially instinctive—is organic. Human cooperation is organized; to this end devices are elaborated by intelligence. Social organization comprehends every adaptation consciously made by thinking, feeling, willing beings seeking to satisfy needs. Because social organization comprehends all conscious interests and, when studied scientifically, must be approached from widely different angles having in mind different objectives, human intelligence when dealing with this broad subject has organized knowledge not as one science but as a very large group of related sciences called “social.” Among the more fundamental of the social sciences are anthropology, sociology, ethics, jurisprudence, economics, political science, and social psychology. Each of these has developed a voluminous literature, which in turn is subdivided into more highly specialized subjects of research. Pursuing a different interest, each social scientist has organized his data around different hypotheses; each has pictured a different phase of social organization. Anthropology (the science of man) in its concrete studies has become narrowed by emphasis given to primitive life and culture. Sociology has introduced perspective, but each sociologist has made a somewhat different approach to his field of inquiry, with the result that the general reader is left confused.

**Conflicting Sociological Theories.** Sorokin, in his introduction to a volume of more than 800 pages written upon the subject

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\* By Frederick A. Cleveland.

of contemporary sociological theories, says: "At the present moment the field of sociology is overcrowded by a multitude of various and contradictory systems. Every novice who enters the field is likely to be lost in it, and what is more important, such a novice has the greatest difficulty in discriminating between what is valid and what is false."<sup>1</sup> This author groups outstanding sociological writers into nine different schools as follows:

1. Mechanistic school: (a) social mechanics; (b) social physics; (c) social energetics; (d) the sociology of Pareto.
2. Synthetic and geographic school of Le Play.
3. Geographical school.
4. Biological school: (a) bio-organismic branch; (b) racialist, hereditarist, and selectionist branch; (c) sociological Darwinism and struggle for existence theories.
5. Bio-social school: demographic sociology.
6. Bio-psychological school: instinctivists' sociology.
7. Sociologistic school: (a) neo-positivist branch; (b) Durkheim's branch; (c) Gumplowicz's branch; (d) formal sociology; (e) economic interpretation of history.
8. Psychological school: (a) behaviorists; (b) instinctivists; (c) introspectivists of various types.
9. Psycho-sociologistic school (various interpretations and experimental studies).

**Conflicting Theories of Other Social Scientists.** An explanation of the meaning of the terminology used above would require more space than is here available. The bare recital, however, is enough to carry the thought that sociologists have not established an acceptable datum-point from which a general survey of social organization may be made. Political scientists are also divided into schools when dealing with their central theme, "the state." They have their mechanistic and organismic schools;<sup>2</sup> their environmentalistic, their juristic,<sup>3</sup> their idealistic schools;<sup>4</sup> their devotees to "the contract theory" of organization.<sup>5</sup> Within

<sup>1</sup> P. Sorokin, *Contemporary Sociological Theories*, Harper's, New York, 1928.

<sup>2</sup> F. Coker, *Organismic Theories of the State*, Chs. II-V, New York; Columbia Univ. Press, 1910.

<sup>3</sup> F. Pollock, *A First Book in Jurisprudence*, New York, Macmillan, 1911; W. Willoughby, *Fundamental Concepts of Public Law*, New York, Macmillan, 1924; J. Austin, *Lectures in Jurisprudence*, London, John Murray, 1879.

<sup>4</sup> I. Kant, *Metaphysical First Principles of the Theory of Law*, in *Metaphysics of Morals*, 1797.

<sup>5</sup> Rousseau, *Contract Theory*, Cole ed., New York, Dutton Co., 1913.

each school there are branches; and each branch contains writers of note who have elaborated theories peculiar to themselves.<sup>6</sup> Analysis of the literatures of economics, ethics, jurisprudence, social psychology, etc., reveals a like controversy and confusion. Within each of the social sciences many theories have been used to set in order the data gathered by scientists and to lay the foundation for interpretation.

**Need for Wider Perspective.** The foregoing analysis and characterization of variant and divergent theories is not presented with a view to raising questions or doubts about their usefulness. Every theory employed scientifically may be true to a purpose served. Each social science, each school, each branch may have used and pursued scientific methods; by research each may have added much to the "sum total of useful knowledge." The thought which the writer would convey is this: that the viewpoint which permits of the widest possible range of vision is one that leaves no part of the field of inquiry out of account. Let us admit, therefore, that the social arrangement to be brought under observation is mechanistic—is analyzable into motor active and controlling mechanisms and is governed by the laws of mechanisms. Let us admit also that the physical units in social organization are organisms, and therefore governed by biological laws. Let us admit that all "human relations" are psychical as well as physical, and therefore are governed by psychological laws. There are still other factors and still other laws which must be recognized when the whole field is seen in perspective.

**Social Organization, a Human Device for Interrelating Personalities.** The only hypothesis which seems to serve the present purpose, that of orientation, is one which conceives of social organization and personality as two aspects of the same thing: in the sense that personality is "an organization"; in the sense that the socialized individual is a "person" whose several "selves" are harmonized under the rule of a dominant ideal self; in the sense that personality as thus organized is the unit in a broadly integrated whole called society. In these several senses self-

<sup>6</sup> A general conspectus of political science theories will be found in Dunning's *Political Theories*, from Rousseau to Spencer; and in Barker's *Political Thought* from Spencer to the present day. A brief summary will be found in many standard works on government such as Garner's *Political Science and Government*, Ch. X, American Book Company, New York, 1928.

organization is a counterpart of group organization; and correspondingly, society is a counterpart of self-organization. Therefore, we may think of all functioning groups into which individuals enter as "associations" of persons which, by the same process of organization, become impersonated. That the thinking, striving self and the self-determining group are two different phases of conscious being is a point of view from which social organization may be seen as a whole. Such a view would seem to be quite in harmony with the thought of present-day educators, moralists, and political scientists as well as social psychologists.

**Group Mind an Aspect of Individual Mind.** The general approach here suggested is not far different from that made by Professor Charles H. Cooley with emphasis placed on "group mind" instead of "personality." In this relation he says:<sup>7</sup> "Mind is an organic whole made up of cooperating individualities, in somewhat the same way that the music of an orchestra is made up of divergent but related sounds. No one would think it necessary or reasonable to divide the music into two kinds, that made by the whole and that of particular instruments, and no more are there two kinds of mind, the social mind and the individual mind. When we study the social mind we merely fix our attention on larger aspects and relations rather than on the narrower ones of ordinary psychology . . . The unity of the social mind consists not in agreement but in organization, in the fact of reciprocal influence or causation among its parts, by virtue of which everything that takes place in it is connected with everything else and so is an outcome of the whole. Whether, like the orchestra, it gives forth harmony may be a matter of dispute, but that its sound, pleasing or otherwise, is the expression of vital cooperation, cannot be denied." The same general thought is expressed by Professor McDougall in his treatise "Group Mind"; by Giddings when he distinguishes "the mind of the many" from the minds of component members; by Wallas in his "Great Society"; by MacIver in his "Community."

**How Human Nature Becomes "Organized."** When attempting to interrelate these two aspects of mind (that of individual and group) Professor Cooley sees in consciousness three phases:

<sup>7</sup> Charles H. Cooley, *Social Organization*, pp. 3-4, New York, Scribner's, 1922.

self-consciousness or what I think of myself; social-consciousness (in the individual sense) or what I think of others; and public-consciousness or a collective view of the foregoing as organized in an inter-communicating and psychically related group. The cor-relatives which run through the chapters immediately preceding this one are: (1) that in the phase called self-consciousness the underlying factor is "an ideal self" around which as a nucleus is organized that unity of thought which constitutes psychological order; (2) that in the phase called group-consciousness (in the individual sense) the ideal self is socialized, the mind of the individual becoming organized as an ethical person by a process of idealization shaped in a social-minded group, the members of which are conscious of a moral order; (3) that in the phase called public consciousness, the mind, feeling, and will express themselves in the establishment of an institutional order, in systems idealized for the purpose of integrating human relations in ways that make for cooperation in the achievement of objective results and instituted by the community.

**Associations as Persons.** Human society has the same biological objective as have the various sub-human collaborating arrangements mentioned in Chapter XIX. The biological end to be achieved is to enable the species to avail itself of the benefits of cooperation. Continuity of human life and its abundance depends on organization as a means of making cooperation effective. Human individuals in physical endowment are among the poorest of God's creatures. They are among the most dependent. Man's compensation for lack of physical endowment is his intelligence. The processes by which organization takes place are discussed elsewhere. The fact here noted is that individuals when guided by intelligence combine with their associates in ways that are thought out. They organize to work together as specialized, functioning groups. They organize as families, as business associates, as philanthropic societies, fraternal societies, cultural groups. The older and more primitive patterns were simple, and the associations formed were exclusive, as shown by chart on p. 529. Modern social organization is more complex and inclusive. The contacts and opportunities for individual self-expression are more numerous. (See chart on page 530.) As the world is now

organized, there is no end to the different kinds of functioning groups into which individuals may enter for their own advantage as well as for the service of the community in which they live

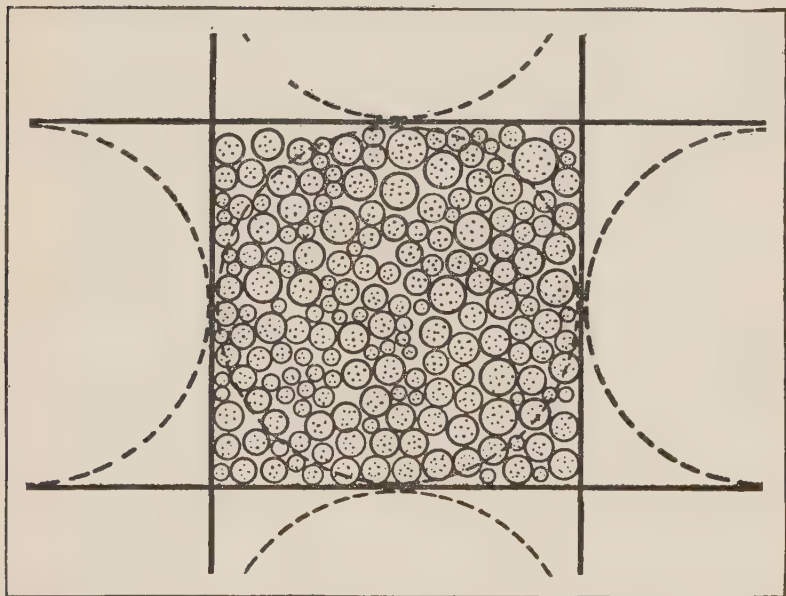


Figure 120. Diagram Showing Simplicity of Town Life in the Middle of the Seventeenth Century. The small circles with included dots represent families—the kindred and economic groups; the large circle represents the church—the religious cultural group; the square represents the town—the politically organized group.

It was in this type of kindred, industrial, social, and cultural institutional complex that the town meeting served as a means of harmonizing the several groups which made up the structure of the community. The means employed was that of constituting each family a constituency, whose head was charged with the responsibility of representing it and its interests in the deliberative, determining council—the town meeting. More strictly speaking, in order to insure capacity for judgment and moral qualifications, only heads of families who were members of the Congregational Church could be members of the governing body—and later the property qualification was added. The heavier lines above are to indicate the effect of this added limitation. (From *National Municipal Review*.)

and of which they are a part. National lines are crossed. Not only are the associations interrelated, but boundaries of exclusive and interrelated communities as well. These interrelated unities in all their working and structural relations are to be accounted

for in only one way: they are made up of unities of the same kind—unities of personality. The “socialized individual,” as a “member,” is a “person” who serves as a constituent or agent of a uni-

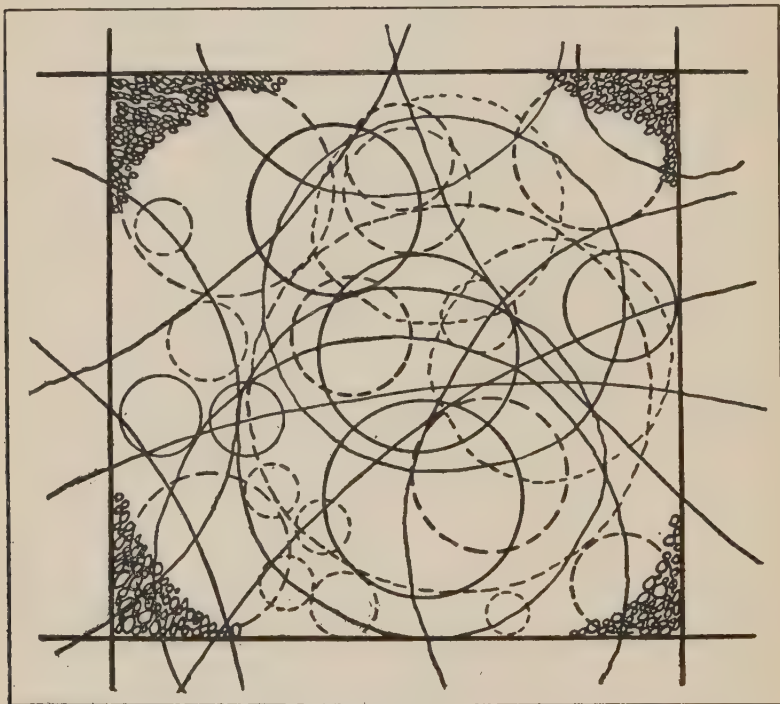


Figure 121. Diagram Showing Complex Institutional Life of a Modern Industrial Town in New England. The small circles, indicating family groups, have been drawn in only at the corners of the graph; solid lines indicate economic groups; broken lines indicate churches; the dotted lines indicate fraternal, philanthropic associations.

In the older type of institutional structure (Figure 120, page 529), it is to be noted that all the groups (family, church, and political) are exclusive; these still remain such. But there are myriads of new organizations whose lines of cleavage intersect family, church, and political boundaries. Each of these has developed new loyalties; organization now overlaps organization; town, county, state, nation, the world, has been felted and drawn together by interests, which gives to us a new problem of constituency and representation. And each member of the family may find himself bound by an entirely different set of interests. (From *National Municipal Review*.)

fied group. The “association” comes to have personality, and as a specialized, functioning personality, serves as the organ of a larger whole, the “community,” which also has the attributes of a

person. In these specialized groups unity is established between the socialized individuals who constitute the "members" in the same manner as the several contending and conflicting "selves" which enter into the personality of the individual himself. (See chart on page 491). The "association" becomes a group person

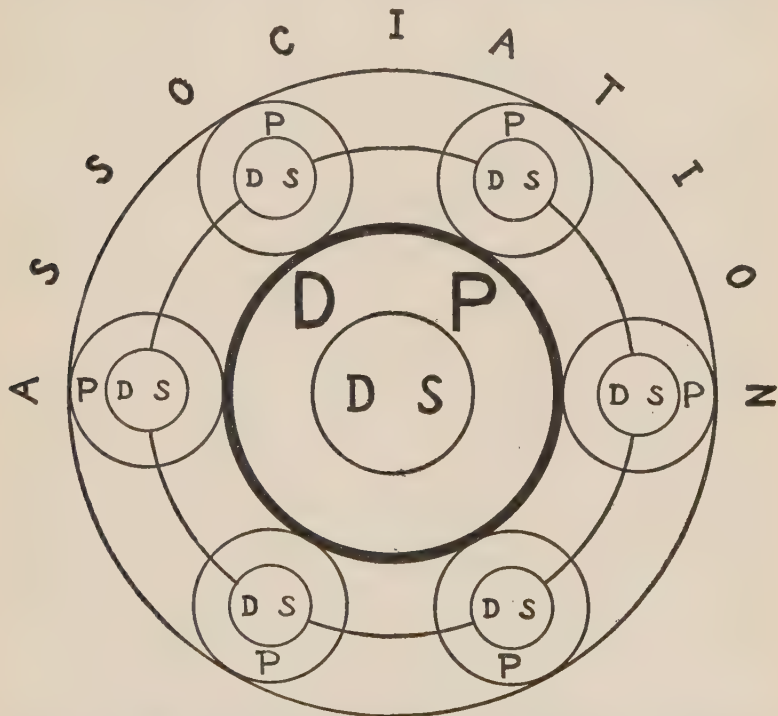


Figure 122. Diagrammatic Representation of the Monad Theory Applied to an Association. An "association" represented as a complex of "persons" who serve as functioning individuals in a group, harmonized and unified under an idealized or "dominant person"—an idealized group, instituted as a socialized and specialized functioning organ of the community.

made up of a unity of individual persons—in which the several members who compose the association, each with his own personality, are harmonized under the rule of an ideal or dominant person, a leader. (See chart above). Each association is capable of doing everything that an individual might do as a unit of organization in the community. The group membership as an organized constituency is capable of thinking together, of

sharing sentiments, holding common loyalties, reaching willed determinations, executing purposes, enjoying rights, discharging duties. It is only when individuals come to be so unified and harmonized as to have personality that they may be said to be "organized." And when organized, associations and communities also constitute unities which have all the attributes of personality.

**Communities as Persons.** "Community" is an area of organized social life. It is something more than individuals. It is something more than a complex of associations. A community must be so organized that it constitutes a person—a social being capable of maintaining a psychological, moral, and institutional order and capable of providing itself with the organ of thinking, feeling, willing, and acting as a person—enjoying and enforcing rights, discharging obligations. The community must be organized as a "person" before individuals and groups can become socialized. The individual person and the group person must be idealized and instituted within a community. Before an individual "person" can exist, the community must take on the attributes of personality; associations must be instituted. The "members" must be conscious of interests in common, share thoughts and feelings, be devoted to ideals, be conscious of an accepted moral order, be made aware of an institutional order. For a definition of and a clear-cut distinction between community and association we are indebted to MacIver.<sup>8</sup> The hypothesis here employed enlarges on the MacIver concept by ascribing personality to "community"—thereby integrating the rights and duties of the larger unity, the rights and duties of unities in a social order all the constituents of which exist as interested "persons."

**Institutions as Idealized Systems of Cooperation.** "Socialized individuals," "associations," and "communities" as persons are the component structural elements brought into relation and combined as "systems" of cooperation. These "systems" constitute an institutional or established order. Institutions are the laws, the rules, the systems of relations approved and established which govern social living and social action. They determine what individual and group behavior is approved and what is dis-

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<sup>8</sup> R. M. MacIver, *Community*, New York, Macmillan, 1924; *The Modern State*, Oxford, Clarendon Press, 1926.

approved. They serve as determinants of rights and wrongs. In this sense, juristic personality is an institution, as is also property; these are fundamental. Instituted "persons" (and the "things" dominated by persons) are combined in approved ways. These group arrangements called "associations" are specialized to serve community needs. The ways and means of achieving purposes are idealized, instituted, and impersonated as specialized systems. Thus each kind of institution constitutes a related code of laws, established and enforced within a community as a system of behavior which may be impersonated.

**Two Uses of the Word Institution.** In adopting the above described conception of institution the writer is conscious of the fact that in common parlance the word has two quite different meanings. In one of its uses the term *institution* has the meaning carried by the title given in such treatises as "The Institutes of Justinian" and in such phrases as "the institutes, the church." In its other common use the term *institution* is merely a synonym of the word "association." Because these are two quite distinct ideas to be expressed, for the sake of consistency we again follow MacIver. As we here use it, the term institutions would include all "systems" of man-made laws governing social behavior; all "relations" which may be entered into, as well as the procedures and formalities attending the bringing of these relations to the focus of public attention. In this sense we speak of the institution of property, the institution of marriage, the institution of sovereignty, the institution of government. Institutions include all systems whereby persons are interrelated and regimented for the achievement of approved objectives governed by man-made laws. The institution of property determines what relations may be entered into by persons by virtue of which they obtain enforceable rights to dominate other persons and things, together with the procedures or formalities that have evidential value in giving notice to the community as to what these relations are. Institutions determine what are the substantive and what are the remedial rights and duties of persons entering into contracts and growing out of relations of membership in organized groups. The institution of betrothal is a formulation of rules governing the relations that may be entered into by affianced persons, to-

gether with all attending procedures. The institution of marriage governs the relations that may be entered into by husband and wife. The institution of the home regulates the relations of members of families. The institutions of partnership, guardianship, trusteeship, bailment, credit, slavery, etc., are among the approved relations which may be entered into, and the systems of behavior prescribed and enforced as between individuals and groups within an area which constitutes the jurisdiction of the community whose welfare is to be served or whose purposes are to be realized through social living.

**Psychological Processes Through Which a Community Becomes Organized.** Much attention has been given by sociologists to the psychological and physiological processes through which individuals and groups become organized and thereby socialized. Professor Edward A. Ross in his "Outlines of Sociology," discussing social forces and the processes of socialization, gives a chapter to each of the following: association, domination, exploitation, opposition, personal competition, class struggle, institutional competition, adaptation, cooperation, organization of effort, organization of will, organization of thought, deterioration of social structures, the rise in gross inequalities, degradation, segregation and subordination, socialization, estrangement, social control, reparation, commercialism, partialization, ossification, decadence, transformation, reshaping.<sup>9</sup> Each of these processes is considered as having a very definite relation to the net result. The evolution of social organization presents many phases. But whatever be the analyses made and the emphasis given, it is thought that among the processes the following should be listed as outstanding: (1) the *idealization* of situations as problems of adjustment; (2) the *institution* of ideals or systems idealized; (3) the *impersonation* of systems which are instituted; (4) the *harmonizing of loyalties*, the coordination of sentiments as a means of unifying the thought, feeling, will, and action of leaders and their respective followers in the various specialized groups which constitute the functioning agencies of communities.

**The Meaning of Idealization.** The word idealization as here used connotes a process by which an ideal is organized. In this

<sup>9</sup> Edward A. Ross, *Outlines of Sociology*, New York, Century Company, 1923.

use one of the best definitions of "an ideal" is that given by John Erskine.<sup>10</sup> A very practical turn is given by him to the conception. His thought is that an ideal is "the solution of a problem"; it is a solution proposed by the imagination, fortified by reasoning based on experience, and enforced by the will. The picture is that of a process or method employed for dealing with a problem of adjustment—a situation which constitutes a dilemma. In this respect it is the same mental process as is described by John Dewey as deliberation—up to the point of determining what one of several alternatives would be best. According to Erskine an ideal goes beyond the exercise of discretion (judgment) in that it involves the organization of the emotions, the gearing up of vital energies to realize the willed determination.

**What Group Idealization Means.** What is meant by group idealization is that the solution must be such that it commends itself to the dominant personnel of the group. The dominant personnel must accept or adopt it, organize their sentiments around the idea as ideal, develop an attitude of loyalty to the ideal. The cooperating individuals must devote themselves to the realization of the visioned solution. Not only must an objective be conceived, but also ways and means must be invented for converting energy into achievement. Group idealization does not differ from individual idealization except that the ideal must be shared; it must become a part of the organized ideal group-self in the same way as if the process were carried on by the individual alone; it must control the behavior of the group or of the idealized person as leader of the dominant personnel before the group can function in the manner idealized. An apt illustration of the idealizing process as such is found in the Constitutional Convention of 1787. There the delegates from twelve of the thirteen independent states got together to dream out a solution of a problem and to resolve the various alternatives imagined into a group judgment—a solution fortified by reason based on experience. Around this accepted solution sentiments were organized. No solution could have served as an ideal which did not secure the devotion of the members of the Convention. The Convention was a specialized organ evolved by thirteen states

<sup>10</sup> John Erskine, *Democracy and Ideals*, New York, Geo. H. Doran Co., 1920, Ch. I.

whose citizens had become "nationally" group-conscious, for the purpose of idealizing a federal government. State constitutional conventions, legislatures, courts, are organs which have a like community use. Every problem which is to be solved by a group must be brought to the focus of attention; alternatives must be resolved into decisions; and decisions must be enforced by the will, through agencies adapted to these purposes.

**What Is Meant by Instituting or Institutionalizing a System.** The above example may be followed to describe what is meant by instituting or institutionalizing an ideal. Idealized systems or solutions must be instituted in the same sense that a machine must be set up or installed. The instituting of a system means not only its adoption, but its integration with other related mechanisms or systems. It was not enough to adopt the Constitution of the United States; before it could be instituted the minds of voters and citizens must also idealize the interrelations of state and local establishments. In a democracy, the process of group idealization begins with leaders as proponents and opponents; from leaders deliberation and determination extend to representatives; when referendum is taken, the process of deliberation and determination must extend to voters; and ultimately deliberation and determination must take hold in the minds of citizens as constituent members of the community. The institution of a system includes an appeal to the emotions as well as to intelligence; it means the organization of the will to act—devotion to the ideal; it means the adoption of the plan, the establishment of rules to govern action incident to the carrying out of the plan of cooperation; it means the integration of the system adopted to make it a part of the machinery of group control. A historic illustration of the process of instituting an ideal which takes the form of a scheme of government is found in the procedures following the Convention of 1787 that terminated in the adoption of the Constitution of the United States. Thereby the new system of interrelated federal and state constitutions became the supreme law of the land. A federated, more highly integrated institutional order was established.

**What Is Meant by Impersonation.** The installation of mechanism is not enough. It must be manned. The adoption of

a constitution does not establish a government. It only creates a body-politic. The agencies of self-determination and action are still to be organized. When the constitution is adopted, political organization has proceeded to the point that a corporation has reached after the original shareholders' subscription-list has been circulated and filed, and the requirements of general law have been complied with to empower the secretary of state to issue a charter to the membership. This charter empowers the members to organize functioning agencies within itself—groups of "natural" persons, who as servants of the corporation as "artificial" person shall be competent to exercise authority, assert the rights, enforce the duties of others toward the corporal body which is served. The statutes which provide for the organization of corporations of a kind (let us say savings banks) plus the acts of individuals who desire to enter into such an association when they join in an agreement to submit to the law, plus the procedural acts that are necessary to give to members powers to organize functioning groups of persons who shall serve the corporation—these acts are not enough to organize an association. Before it is completely organized, before it is competent to think, feel, will, and act as a "person," the association as "artificial person" must be actually with flesh and blood; the needed living agents as servants must be actually chosen and installed. This last step is the process of impersonation. The same reasoning in fact may be applied to the legal impersonation of an individual, as set forth in Chapter XXIX. An individual who possesses legal qualifications is not, merely because of this, competent to exercise rights and discharge duties. The individual person as well as the group person must be first idealized as an instrument of social service. First there must be a long process of "e-ducation"; then evidence of competence to exercise moral discretion; then evidence of such maturity that capacity for self-determination and competence in the management of affairs may be assumed. Finally, the individual must actually enter into association, become integrated with other persons, before the individual person is a going concern. Impersonation, the clothing of systems of individual and group behavior with flesh and blood, must be thought of as one of the essentials to social organization, even in the most simple of social arrangements.

**The Impersonation of a Community.** Not only must the individual and the association be idealized, instituted, and impersonated in social organization, but the community as well. Such a conception is fundamental when thinking about community life, no matter how simple or complex. The community may be as simple as a patriarchal family or as complex as a world empire. In the first case the family community is impersonated by the patriarch; in the second case the empire may be impersonated by the monarch. In a democracy an idealized nation is impersonated as sovereign. In setting forth the principles which govern social organization the framers of the constitution of Massachusetts idealized the commonwealth and impersonated it as a sovereign people, a politically organized group, mentally, morally, and legally competent to determine what organs or agencies should be employed to conserve the common welfare. And the people of Massachusetts thus impersonated as sovereigns (already having among them many different types of associations for cooperative achievement) instituted another association which would be a dominant body-politic. Thereby Massachusetts after the revolution became politically organized. This was the act which made "the people of Massachusetts" acceptable as a politically organized community—determined their fitness to exercise powers of sovereignty. Quoting from the language of the founders, accepted and adopted as fundamental principles: "The body-politic [the state] is formed by a voluntary association of individuals [citizens as members of the community]; it is [organized by] a social compact, by which the whole people covenants with each citizen, and each citizen with the whole people, that all shall be governed by certain laws [institutions] for the common good." But the body-politic as an association (of voters) to which are assigned specialized functions, could do nothing as such until the state had provided itself with fitting instrumentalities. Therefore, the community adopted a constitution, provided for functioning agencies, set up rules governing the actions of voters, and chose public servants to exercise powers. The body-politic was idealized and instituted as a dominant association; voters as members of the body-politic were given power and made responsible for determining who should exercise authority. In this idealized scheme the older order was reversed. Instead of a royal

person—the one who exercised powers (a monarch or a government) being sovereign, and the community and the various functioning groups other than the state being subject—the people were made sovereign; all associations, including the state, were made subject; and those exercising authority were made servants—legislators, executives, judges—they became servants or subjects of the sovereign community whose members were the beneficiaries of the trust.

**The Federation as Community of Communities.** What is known as the United States of America is a federation. It is not an alliance of bodies-politic; it is a federation of communities (local commonwealths). An alliance entered into by bodies-politic is a *league, not a federation*. A league may serve an immediate purpose. Such an arrangement was entered into under the Articles of Confederation adopted in 1781. Such an arrangement was entered into by other nations after the World War. The organization which followed the American Confederation was an integration of thirteen idealized, legally impersonated communities (commonwealths) into a larger community, the American people. This was a social arrangement in which the several communities were unified, harmonized, made cooperative by the creation of an idealized institutionalized dominant community—not of the fashion of “the German federation” in which one of the federated communities (Prussia) dominated, but one newly created and independent, composed of citizens of the United States. The people of the United States (citizens of the federated commonwealth) when entering into this new compact were endowed with rights and duties distinguishable from the rights and duties of citizens of each of the included commonwealths. And the people of the United States impersonated as a nation came to have rights and duties that other nations, as well as the included states, were bound to respect. Such is the meaning of the Declaration of Independence. Such, also, is the assumption which lies back of the American federal constitution, under which the nation organized its dominant association as “the government of the United States” and acquired for itself dominant sovereign personality. Communities small or large, simple or complex, solitary or interrelated, cannot be idealized except in terms of personality. Such a concept

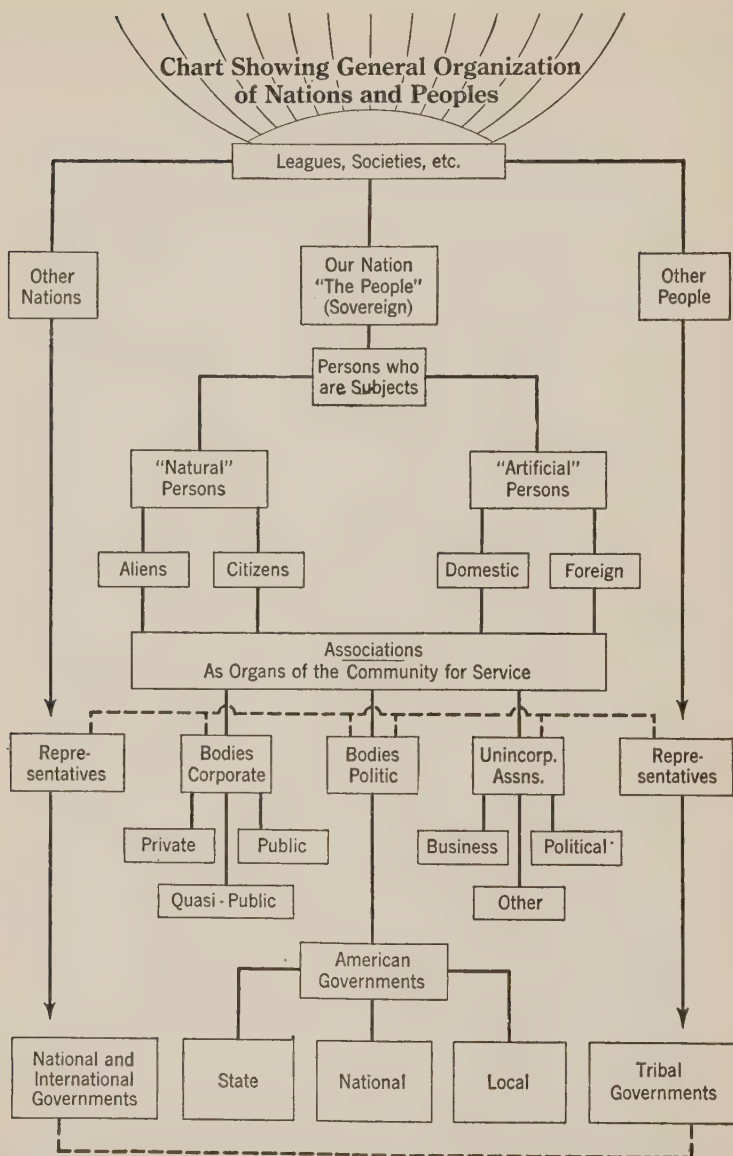


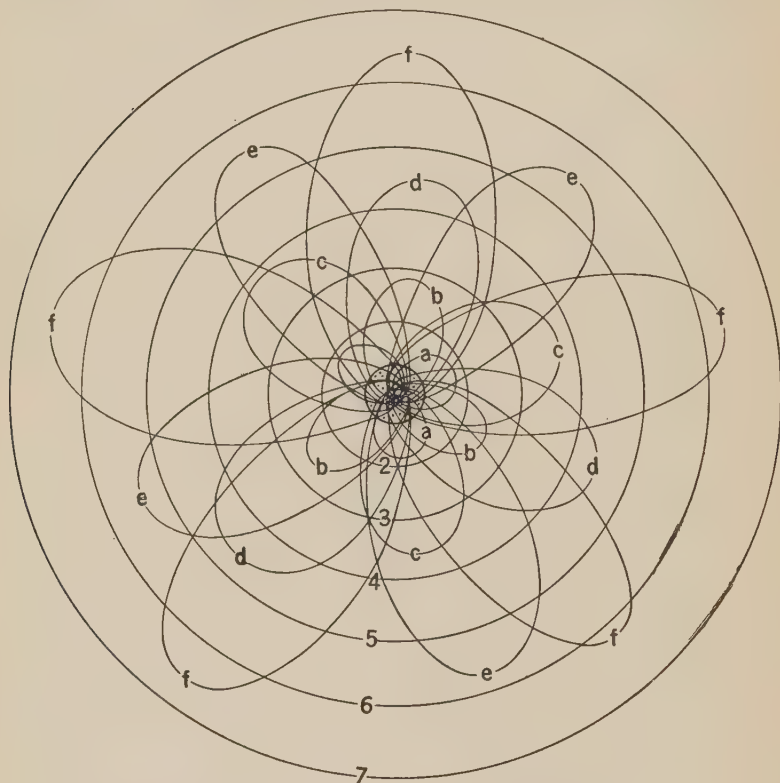
Figure 123. Chart Showing General Organization of Nations and Peoples. This chart is designed to show that all leagues and communities, whether simple or complex, are interrelated, and function through agencies, individuals, and groups which impersonate them.

of world order is graphically portrayed on page 540. Conceptions of personality and processes of impersonation are necessary to idealization. We may have an idea without impersonating it as an idea; for example, a horse, or a steam engine, or a solar system. But an idea which serves as a guide to the behavior of self-determining moral beings must be impersonated. It may be impersonated as an ideal to which we become devoted and which speaks to us as with the voice of authority coming from our own dominant selves as conscience; it may be impersonated as an ideal which speaks with the voice of some dominant person—as of God or of the devil; we may think of the ideal impersonated in someone whom we accept and look up to as our cultural leader (our parent, our pastor, our tutor) or in someone in command of an action-group (as master, captain, chief, governor, president); we may think of the ideal impersonated in a social leader, or as dealing with any problem or interest which may attract “persons” and cause them to “associate” themselves under “dominant persons.”

**The Problem of Loyalty.** The feeling tone and the sentiment of devotion organized around a person, or an ideal impersonated in an organized group, is “loyalty.” One of the precepts of our political faith is: “Ours is a government of laws and not of men.” This is a slogan indicative of a relation in which our highest loyalty is to an impersonated ideal. Not that government can exist without “natural persons”—who can speak with authority, and to whom we will be loyal—but our superior political loyalty is to the “artificial person” clothed with supreme power, “the people.” The precept noted above speaks of a system in which the community (the people) is impersonated as sovereign; the citizenry are subjects (including all their idealized associations which under our constitution are citizens as well); the body-politic is one of these subject-associations—the dominant association under and through which all personalities and impersonated groups are harmonized. In this system the bonds of union are coordinated loyalties. The need for coordination is obvious. A hierarchy of personalities in organization calls for a hierarchy of loyalties without which there must be a confusion of voices. The assumption

is that "we, the people" as organized personalities obey that urge, that voice, which speaks in terms of the highest good.

**The Highest Loyalty.** The principle laid down is this: that everyone, as a responsible person, before he decides what course



#### CONCENTRIC JURISDICTIONS

1. The family
2. The town
3. The county
4. The state
5. The nation
6. The society of nations
7. The world

#### GROUP LOYALTIES

- a. Town group activities
- b. County group activities
- c. State group activities
- d. National group activities
- e. International group activities
- f. Activities for good of mankind

Figure 124. Chart Showing the Different Concentric Jurisdictions to Which the Individual Members of a Family Are Subject, and the Many Groups to Which One or Another May Owe Loyalty.

he will pursue in the solution of a problem of conflict, shall sit in critical judgment on: (1) the question as to which "self" shall

be idealized, instituted—which self he himself will impersonate; (2) the question—in associations with other people—as to which leader or call to duty he will follow; and (3) the question—as member of interrelated communities (town, state, nation, empire)—as to what is the highest good. On last analysis each individual must decide which action will most nearly accord with a concept of justice that is as inclusive as human nature, mankind, humanity—how will he harmonize his loyalties to the end that his life may be lived in harmony with his fellows and in harmony with that conception of goodness and greatness which he idealizes and which is idealized in the several interrelated communities of which he is a member. (See chart on page 542.)

**Loyalty a Product of Culture.** Loyalties are organized. The outstanding cultural agencies are the church, the state, the home. As a guide to moral judgment, the individual impersonates God or Humanity or the moral order as the Supreme Good. Therefore, as a responsible moral being, each individual sits in judgment not only on his own loyalty, decides what “self” he will follow, but he also sits in judgment on the loyalty of leaders as impersonations of the goods to be conserved in associations dominated by them. And because each is aware of the fact that it is human to err (when given the authority to lead as well as when placed under obligation to obey), the individuals who constitute a community have set up among themselves a dominant association (the body-politic) as an idealized person whose function it shall be to reconcile and harmonize loyalties. The nation being idealized and impersonated as sovereign, the body-politic thereby becomes the organ through which the will of the sovereign is organized, expressed, and executed. Among the cultural functions of the church is the organization of religious and moral sentiments. By means of the body-politic, instituted ideals and action systems are kept in adjustment. Our political system is in the nature of an impersonation of nationality, country, native land. Patriotism is devotion to institutions. In democracies love of country has taken the place of service to a lord or king. Thus, loyalty to “the people” impersonated as sovereign serves not only as a common bond, but also harmonizes loyalties and purposes to be conserved through associations. Loyalty to “the government

of the United States" and loyalty to "the commonwealth" in which one lives, unifies all other interests and purposes. This ideal, this solution of the problem of living cooperative lives, we hold to with a devotion which, if need be, leads us to sacrifice our properties and our lives in a common cause. As, in the moral and spiritual realms, we hold to an impersonation of Goodness as supreme—so when dealing with conceptions of legal rights and duties we hold that loyalty to country and allegiance to government are supreme. To us as Americans patriotism means not alone an attitude toward an objective which is analyzable in terms of physical well-being, but also devotion to a psychical and moral order which we call democracy—a moral order in which everyone is assumed to be free—a régime in which everyone is guaranteed the legal right to choose his career and make the most of it, an impersonated ideal that is sovereign, and from which we gain a right to live objectively our own highest inner lives.

**Harmonizing Lower with Higher Loyalties.** Social organization, in the last analysis, is a matter of harmonizing loyalties: loyalty of followers to leaders; loyalty of leaders to ideals shared by followers; loyalties of "artificial persons" (associations) to "dominant artificial persons"—the states. Democratic government is an idealization of a system adapted to harmonizing the loyalties of leaders in highly specialized associations by holding them responsible. The responsibility of persons in authority is first to the "constituent members" of the state. But responsibility to the state, a service association, is to that larger group, the community. Political organization is a means to an end—the end being to develop and use group consciousness of right (public consciousness of justice) to conserve the common welfare. The social purpose of electorates, parliaments, courts, executives, controllers, etc., is to subordinate small group loyalties to large group loyalties, and to subordinate persons in authority to an ideal of service to the community as opposed to self-enlargement and exploitation. Sentiments organized around these commonly shared ideals have their negative as well as their positive aspects. The negative aspect of the revolt against British authority in 1776 was a bitter resentment of two-thirds of the people against the other third who believed in class domination. This resentment

not only ran against the dominant class, but also against the use of fear to make men subservient to exploitive leaders. The positive aspect of the American Revolution was the organization of a constructive ideal—an ideal of control over deliberative and executive leadership to make it subservient to the will and purpose of the people. Correlatives to the negative principles of opposition to class domination, tyranny, and exploitation were the positive principles of popular sovereignty, good-will, and organization for service.

**The Loyalty of Leaders.** The powers of leaders are powers organized in and expressed through organization. Potentially the effectiveness of social organization depends on the strength of the bonds which hold men together as vital motor mechanisms and upon the intelligence shown in giving direction to their combined efforts. In the human machine the psychical ties may prove as weak as thin air or stronger than bands of steel. The more usual treatment of loyalty emphasizes the need for the devotion of followers to their leaders. The principle here laid down is that put forth by Josiah Royce that the greatest loyalty is loyalty to a cause—an ideal—impersonation of which is found in those whom we choose as leaders. Loyalty to a cause throws emphasis on that dominant “artificial” personality necessary to the unification of groups as well as individual lives. This means that the leader must be loyal to the idealization of that purpose the achievement of which is the *raison d'être* of the association dominated by him. The disloyalty of a leader to the cause which he represents can have no other result than to subvert the enterprise. Loyalty to a disloyal leader must necessarily result in complete moral degeneration in the group or in destructive feuds between the warring small groups that are organized for exploitive or selfish achievement. Autocracy is the product of loyalty to leaders who are disloyal to the interests of the community. Aristocracy is a class ideal. Its cultures are designed to promote loyalty to the welfare of a class. The chief end and aim of all democratic conceptions of social organization is to provide means for developing a sense of common loyalty and for protecting the community against the disloyalty of self-seeking and class-minded leaders. In brief, the general conception of social organization is this: the smallest con-

stituent units with which we have to deal are socialized individuals; the ways and means provided for cooperative activities are associations; the rules governing action are institutions; the processes by which social organization takes place are those of idealizing solutions of group problems, instituting ideals, impersonating institutions, organizing and harmonizing the sentiments which at once serve as bonds of union and as motives to cooperative achievement.

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Analysis of behavior (cont.), pp. 293-299; Ch. XVIII, Analysis of behavior (cont.). pp. 300-313; Ch. XX, Relation of behavior in lower organisms to psychic behavior, pp. 328-337.

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